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THE STRUCTURE OF ATOMS

ALL MATTER is composed of atoms, incredibly large numbers of them. Until relatively recent times it was believed that atoms were tiny, solid, indivisible particles, an idea that was first expressed by the Greek philosophers of some 2000 years ago. Indeed, the word atom is derived from the Greek ***atomos,*** a word which means ***indivisible***. By the turn of the present century scientists were sure that this concept of indivisibility was wrong. There was evidence that atoms consisted of two parts. This was confirmed by Lord Rutherford, who did part of his research at McGill University. In 1910 he showed that the atom consisted of a small, positively charged core (which is called the nucleus), and electrons which occupied the space about the nucleus and determined the "volume" of the atom. Niels Bohr, a Danish scientist, made the first attempt to show the distribution of these electrons.

What Are Electrons? An ***electron*** is a particle of negative electricity. The number of electrons in the space outside the nucleus is the same as the number of positive charges in the nucleus. The electron charge, therefore, neutralizes the positive charge on the nucleus, so that an atom under normal conditions is neutral. The lightest atom is hydrogen. The hydrogen atom has a nucleus consisting of a single, positively charged particle of matter called a ***proton***. To maintain a neutral atom it has one electron occupying the space about this proton. The heaviest natural element is uranium. A uranium atom has 92 protons in the nucleus surrounded by 92 electrons.

Scientists have determined the weight of electrons. They are exceedingly light —the weight of an electron is only about 1/1800 as heavy as a hydrogen atom. Nevertheless, these tiny negatively charged particles can do many things. If electrons flow through a wire they constitute an electric current — about 6 billion billion (6,000,000,000,000,000,000) of them pass through the filament of a 100 watt light bulb every second. If they sweep across a cathode ray tube they may form a television picture, and finally, they take part in all chemical reactions. Indeed, the chemical properties of atoms are determined by the number and distribution of the electrons. If there are 29 electrons in a neutral atom, the atom is copper; if there are 26 electrons, the atom is iron; if there are 82 electrons the atom is lead.

How Are The Electrons Arranged? Electrons are not arranged in haphazard fashion about the nucleus but, as we shall see, they arrange themselves in a particular pattern. An electron does not occupy a

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single position. It may be found anywhere about the nucleus, but certain regions are much more likely to contain a given electron than others. The most probable distance of an electron from the nucleus or, stated another way, the region the electron occupies depends upon the amount of energy possessed by the electron. The greater the energy the further is the distance from the nucleus, and so we say the electron occupies certain energy levels. These energy levels are numbered as 1, 2, 3, etc., the closest to the nucleus being number 1. Each energy level is subdivided into orbitals. It is found that the number of orbitals in each energy level is equal to n^2, where n is the number of the energy level. Moreover only two electrons can occupy each orbital, therefore, the maximum number of electrons in a given energy level is equal to $2n^2$. Thus, the number 1 energy level can only hold two electrons, the number 2 energy level can hold eight (2×2^2) electrons, and the number 3 energy level 18 (2×3^2) electrons, and so on.

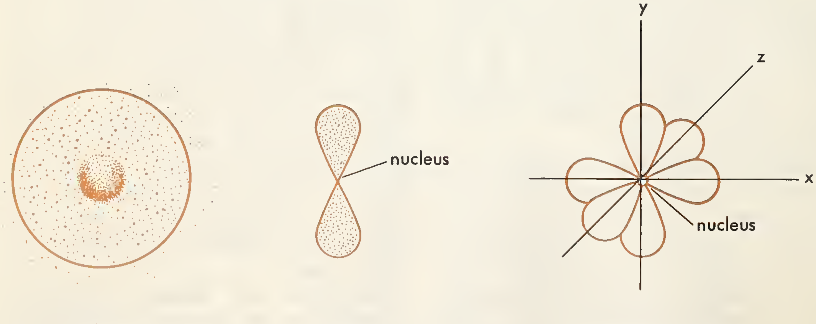
Each energy level is made up of several sub-levels or orbitals, very close together, and usually designated by the letters s, p, d, f. The first two electrons in a given energy level occupy an s orbital. The next six occupy three p orbitals. The next ten occupy five d orbitals, and the next 14 occupy seven f orbitals. The s and p orbitals are the most important in the formation of simple compounds.

As already mentioned one cannot tell the precise position of an electron at any given time, but one can tell in what region of space about the nucleus the electron will probably be found. This is similar to the following description of a student's whereabouts. A certain student will be most likely at school on any particular school day. The school would be the most probable place to expect to find him. However, on any particular day he might be home sick or just taking an unofficial holiday. We could draw a ring around his school and say that he will be found within that ring 90% of the time on a school day.

So we can also show an orbital in this way. We will illustrate a volume of space in which one could find the electron 90% of the time. Remember, although our drawing is on a flat surface, it is intended to show a volume.

An s orbital is spherically arranged about the nucleus as shown in Fig. 19-1. The intensity of the dots gives us the

Fig. 19-1. The probability patterns of electrons in s and p orbitals.



s orbital

The nucleus would
be at the centre
of this sphere.

p orbital

arrangement of the
p_x p_y and p_z orbitals

most probable place for the electron and the boundary defines a volume within which the electron will be found 90% of the time.

There are three p orbitals. These are oriented in each of the three directions in space at right angles to each other — one about the X axis, one about the Y axis and one about the Z axis, as shown in Fig. 19-1. You will notice that the probability pattern assumes the shape of two balls joined at the nucleus.

These are all probability patterns and tell us simply that if we are looking for a particular electron it will be found within the boundaries of these patterns 90% of the time. Remember that each orbital can contain two electrons.

What Is a Nucleus? Scientists have even explored the nuclei of atoms and have discovered that they consist primarily of two kinds of particles, protons and neutrons. Protons and neutrons have about the same weight (both are about 1800 times heavier than an electron) but electrically their properties are quite different. A proton carries a positive charge of electricity. A nucleus of a hydrogen atom consists of a single proton whereas a nucleus of a uranium atom contains 92 protons.

A neutron, on the other hand, is a particle without charge — a neutral particle as the name suggests. An atomic nucleus is therefore an aggregate of a certain number of protons and neutrons. It follows that the total number of particles in a nucleus constitutes the atomic weight of that particular element, the weight of the electrons being negligibly small. The nucleus of an oxygen atom, for instance, consists of eight protons and eight neutrons and hence its atomic weight is 16. On the other hand, the nucleus of a uranium atom does not consist of equal numbers of protons and neutrons. Instead it is an aggregate of 92 protons and 146 neutrons, so that its atomic weight is 238.

It should now be apparent that almost all of the mass of an atom is concentrated in the nucleus, yet Rutherford discovered that the nucleus is about 1/100,000 the size of the atom itself. Or, expressed another way, if an atom could be magnified to the size of a house, the nucleus would be no larger than a grain of sand. With this picture in mind it is clear that an atom is mostly empty space.

The Periodic Chart Tells the Atomic Structure. Notice the periodic chart placed inside the back cover of this book. You will see that there are 103 different elements arranged in numerical order. For each element the periodic chart gives the following information. Above the atomic symbol is the atomic number. Below the symbol is the atomic weight, and in the column to the left of the atomic symbol is shown the arrangement of the electrons according to the various energy levels.

The atomic number tells us the total number of electrons per atom — all outside the nucleus. It also tells us the number of protons in the nucleus. Thus it is that all neutral atoms have an equal number of positive charges (protons) and negative charges (electrons). The atomic weight tells us the total number of protons plus neutrons. That is to say the weight of the electrons is negligibly small so that the mass of the atom is thus made up almost completely by the masses of the protons and neutrons in the nucleus.

Now, with this information we are ready to draw a diagram which will give us some idea of the structure of the atom. We must remember, however, that the picture we draw is not necessarily what the atom would look like if we could see it but rather it is a convenient way of illustrating a number of important properties of the atom. This is just a convenient model which takes into account all the experimental facts known and will help us to predict further facts about the atoms and how they combine. To describe the atom more completely we must use mathematical equations. Many groups of scientists called theoretical chemists and

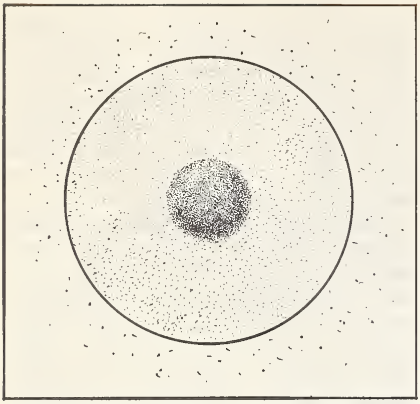


Fig. 19-2. The probability pattern of the hydrogen atom. The atom consists of a single proton and a single electron.

theoretical physicists are only now developing and solving the necessary mathematical equations.

A Hydrogen Atom. A hydrogen atom is the simplest of all atoms. It has an atomic weight of 1.008 and an atomic number of 1. The atomic number tells us that there is one proton in the nucleus and, since all atoms are neutral, there is a single electron outside the nucleus. A model of a hydrogen atom is shown in Fig. 19-2. The probability pattern of the electron would resemble a fuzzy sphere with the nucleus hidden in the centre. The single electron is in the 1 energy level and it can be designated as a $1s^1$ electron. This nomenclature $1s^1$ tells us that there is one electron in the 1s orbital. Since the atomic weight is approximately 1 and since we know that there must be one proton in the nucleus we can conclude that there are no neutrons in the nucleus. The hydrogen nucleus is, in fact, the only nucleus that contains no neutrons.

A Helium Atom. Although helium is next to hydrogen in lightness, helium atoms are considerably more complex than hydrogen atoms. The atomic number of helium is 2 and its atomic weight is 4.003. The atomic number tells us that there are two electrons in the 1 energy level of the helium atom and two protons in its nucleus. However, we know that its atomic weight is approximately 4. To account for this atomic weight we must conclude that there are two neutrons as well as two protons in the nucleus. This is shown in Fig. 19-3. The two electrons of a helium atom are designated as $1s^2$ which tells us that they are in the 1s orbital. Since these electrons are in an s orbital, their probability pattern is a sphere about the nucleus.

Fig. 19-3. The helium atom has two protons and two neutrons in the nucleus. The two electrons have been omitted to expose the nucleus. On the same scale used for the size of the nucleus, these two electrons would occupy a fuzzy sphere about the nucleus that was over 1 mile in diameter.

Helium atoms are chemically inactive and this two-electron arrangement is therefore a stable structure. In other words no more electrons can fit into the 1 energy level. The next element listed must arrange its extra electrons in a second energy level, which is further out from the nucleus of the atom.

A Lithium Atom. The atomic number of lithium is 3 and its atomic weight is 6.940. A lithium atom must therefore have three external electrons. To account for the atomic weight of approximately 7 the nucleus must contain 3 protons and 4 neutrons. The electrons are described according to the following notation:

$$1s^2 \quad 2s^1$$

The 1s orbital is filled with two electrons and the third electron is in the 2s orbital. Again notice in the periodic chart that this is indicated in the column to the left of the atomic symbol. The column shows first the number 2 which tells us that there are 2 electrons in the first energy level and then below this the number 1 which tells us the number of electrons in the second energy level.

The lone electron in the second energy level is very loosely held, making lithium metal very reactive. Indeed this outermost electron takes part in all chemical reactions of the element lithium.

The Electron Distribution of Other Atoms. The electron arrangement showing the orbitals of the first eleven atoms is shown in the following table:

THE DISTRIBUTION OF ELECTRONS IN SOME ATOMS

Atom	*Orbital Arrangement of Electrons*					
H	$1s^1$					
He	$1s^2$					
Li	$1s^2$	$2s^1$				
Be	$1s^2$	$2s^2$				
B	$1s^2$	$2s^2$	$2p_x^1$			
C	$1s^2$	$2s^2$	$2p_x^1$	$2p_y^1$		
N	$1s^2$	$2s^2$	$2p_x^1$	$2p_y^1$	$2p_z^1$	
O	$1s^2$	$2s^2$	$2p_x^2$	$2p_y^1$	$2p_z^1$	
F	$1s^2$	$2s^2$	$2p_x^2$	$2p_y^2$	$2p_z^1$	
Ne	$1s^2$	$2s^2$	$2p_x^2$	$2p_y^2$	$2p_z^2$	
Na	$1s^2$	$2s^2$	$2p_x^2$	$2p_y^2$	$2p_z^2$	$3s^1$

Notice that the second energy level designated 2 can hold eight electrons and that both s and p orbitals are used.

A Neon Atom. The nucleus of the neon atom consists of 10 protons and 10 neutrons. Therefore there are 10 electrons outside the nucleus. These are distributed as shown in the table. You will notice that there are two electrons in the inner energy level, and eight in the outer energy level. We can show the distribution as in the table, or, for convenience, as $1s^2$ $2s^2$ $2p^6$. We have already stated that the outermost energy electrons govern the chemical properties of an atom. But neon has no marked chemical properties. That is to say it is relatively inert. Its chemical stability is due to the fact that there are eight electrons in the outer energy level. This is a stable structure. Hence, the next heavier atom, sodium, starts a third energy level for its outermost electron.

As the atomic number of the atom increases its nucleus becomes more massive and the arrangement of the electrons more complex. It will become necessary to use d orbitals and finally also f orbitals in accounting for the arrangement of the electrons about all the known elements.

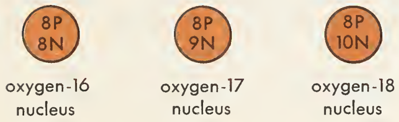
A Uranium Atom. The heaviest natural occurring atom is that of uranium with an atomic weight of 238. The massive nucleus of this element contains 92 protons and 146 neutrons. Indeed the nucleus is too massive to remain stable and it decomposes spontaneously, a radio-active process discussed in Chapter 33. The complete electron arrangement would be designated as $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $3d^{10}$ $4s^2$ $4p^6$ $4d^{10}$ $4f^{14}$ $5s^2$ $5p^6$ $5d^{10}$ $5f^3$ $6s^2$ $6p^6$ $6d^1$ $7s^2$.

ISOTOPES

At one time it was thought that all atoms of the same element were exactly alike. It was believed, for example, that all oxygen atoms have a weight of 16. We now know, however, that the atomic weight of most oxygen atoms is 16, but that for some the atomic weight is 17, and for a few it is 18. How can this be? All oxygen atoms have the same chemical properties and therefore they all have the same number (8) of outer electrons. This, in turn, means that all have the same number of protons (8) in the nucleus. Hence the only way to account for the differences in weight is by differences in the number of neutrons. A difference in the number of neutrons does not affect the number of electrons so that the chemical properties of the atoms are in no wise changed. The nucleus of oxygen-16 contains 8 neutrons; oxygen-17 contains 9 neutrons; oxygen-18 contains 10 neutrons. These different atomic forms of oxygen are called ***isotopes.***

Isotopes are simply atoms of the same element but with different weights. Almost every element has two or more natural isotopes: carbon has two, nitrogen two, oxygen three, and even hydrogen has three. An isotope of hydrogen called deuterium or heavy hydrogen has a double-weight nucleus consisting of a proton and a neutron as shown in Fig. 19-5. Tritium is the third isotope of hydrogen, its nucleus consisting of a proton and 2 neutrons.

Fig. 19-4. The nuclei of the three isotopes of oxygen; oxygen-16, oxygen-17, and oxygen-18.



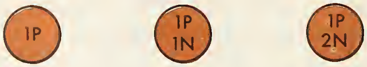


Fig. 19-5. The nuclei of the three isotopes of hydrogen.

Or again there are two isotopes of copper. About two-thirds of copper atoms have an atomic weight of 63 and the rest have an atomic weight of 65. Can you now draw diagrams of the nuclei of the isotopes of copper?

Stability of Isotopes. Since most elements have only a few stable isotopes, it follows that there are only a few stable combinations of protons and neutrons. We shall read later, in Chapter 33, that it is a fairly easy matter to add an extra neutron to the nucleus of an atom. But when a nucleus is penetrated by a neutron it usually becomes unstable and disintegrates.

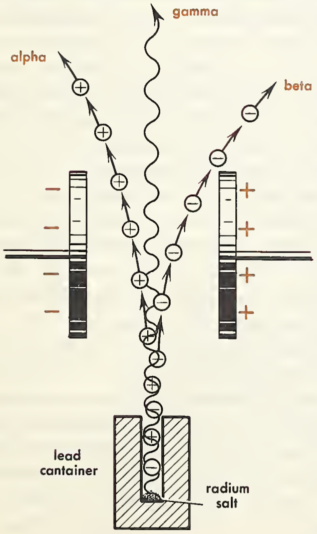
Probably the most interesting isotopes are those of uranium (atomic weights 235 and 238), usually called U-235 and U-238. U-238 is far the more plentiful isotope. Actually natural uranium is a mixture of 99.3 per cent U-238 and 0.7 per cent U-235. U-235 is the explosive kind. That is to say, its nucleus splits into two nearly equal parts if it is penetrated by a single neutron, a process called ***fission.*** U-238, on the other hand, does not explode in this way; its nucleus can absorb a neutron without splitting. This marked difference between the two isotopes made it necessary to separate them before the U-235 atomic bomb could be made.

Radioactivity. It was the study of radioactivity that provided most of the clues in the early investigation of atomic structure. Radioactivity was discovered by accident in 1896, when a French scientist named Becquerel placed a lump of uranium ore on a box of photographic plates.

When the plates were later developed, they were all found to be fogged. Why? This to Becquerel was an intriguing question. He concluded that uranium atoms shot off invisible radiations capable of penetrating the cardboard box and fogging the photographic plates. These radiations are a form of energy. Where did the energy come from? Was it supplied by atoms of uranium? Becquerel strongly heated the ore and then cooled it to a low temperature. But the radiations escaped at the same rate and there was nothing he could do to change this rate. Becquerel had stumbled upon a new and fascinating field for scientific research.

Although radioactivity was discovered by Becquerel, the metal uranium had been known for more than a century. Actually it was discovered by a German chemist named Klaproth in 1789. The chief use of uranium compounds had been to add color (ruby, orange or yellow) to glass and porcelain. The stained glass windows of many European cathedrals, for example, are colored by uranium compounds. And the uranium used for this purpose was extracted from pitchblende, a hard, black uranium ore found in Czechoslovakia.

Fig. 19-6. Alpha and beta particles are deflected by an electric field but not gamma rays.



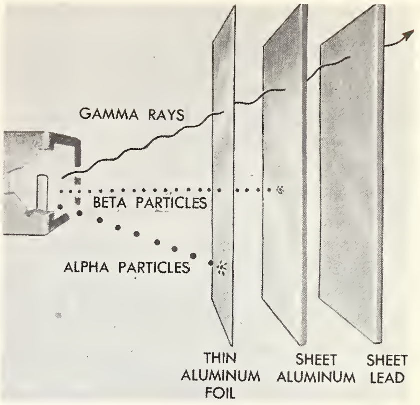


Fig. 19-7. Alpha particles are stopped by thin aluminum foil. Beta particles are stopped by an aluminum sheet 1 cm. thick. Gamma rays will penetrate sheet lead 5 cm. thick.

The Curies. Marie Curie and her scientist husband, Pierre, close friends of Becquerel, began work in this new field. First the Curies discovered the remarkable fact that pitchblende was more radioactive than uranium itself. How could that be? Apparently the ore contained an element more radioactive than uranium and the Curies set about to find it. This tedious and strenuous task kept them occupied for nearly four years. Finally success came. From one ton of pitchblende they obtained a minute quantity (about the size of a pinhead) of a new element which was about 1000 times as radioactive as uranium. This new element they called ***radium.***

Radiations from Radium. What kind of radiations are emitted from radium? From what part of the atom do they come? These questions were investigated by the British scientist, Lord Rutherford. He found three different kinds of radiations. Some were positively charged, some were negatively charged, and some were not charged at all. He called them alpha, beta, and gamma rays.

Alpha rays are really positively charged particles. These particles are composed of two protons and two neutrons which break away from the larger nucleus; they are, in fact, the nuclei of helium atoms.

Beta rays are negatively charged particles; they are electrons. But how can electrons escape from a nucleus that consists only of protons and neutrons? A neutron can be changed to a proton and an electron. Indeed, this is one of the changes in the radioactive process. When the change takes place the released electron is shot out of the nucleus at high speed, almost at the speed of light.

Gamma rays, on the other hand, are not particles; they do not consist of protons, neutrons or electrons. They are electromagnetic radiations ***similar to X rays*** and travel with the speed of light. They are highly penetrating and can pass through a steel block a foot thick. They can also penetrate human tissue, so that prolonged exposure to them is highly dangerous.

Radioactive Disintegration. Every known ore of uranium contains, besides uranium, such radioactive elements as thorium, radium, radon, polonium and bismuth, as well as lead that is not radioactive. Why this mixture of elements? Let us remember that both alpha and beta particles come from the nuclei of atoms. The "atomic" weight of an alpha particle is 4, since it consists of two protons and two neutrons. Therefore, if a nucleus shoots off an alpha particle an entirely new nucleus is formed; that is, a new element results from the loss of an alpha particle. Similarly, before a nucleus can eject a beta particle a neutron must be changed to a proton and an electron. Thus when this electron is emitted, the number of protons in the nucleus is increased by one and again a new element is thereby formed.

It is now apparent that the nuclei of radioactive atoms are unstable. Starting with the heaviest element, uranium, 14 nuclear disruptions occur before a stable nucleus is obtained. The stable nucleus is that of lead, and here radioactivity stops. When the Curies set out to find the potent radioactive element in uranium ore they little realized that the ore contained 14 different kinds of atomic nuclei. Even today the only way that radium is obtained is by the laborious extraction of it from a uranium ore containing only a minute fraction of radium. That is why radium is so expensive—it costs about $25,000 per gram—and why it is so fantastically scarce—the total weight of all the radium in the world does not amount to more than 5 pounds.

The Age of Radioactive Elements. We have said that when a radioactive atom blows up it releases some of its energy and forms an entirely different element of less mass. The "lives" of radioactive elements vary enormously—some are exceedingly long, others are exceedingly short. Scientists speak of the "half-lives" rather than the "lives" of radioactive elements. ***The half-life of a radioactive element is the time required for half of its atoms to disintegrate.***

Uranium has the longest half-life among the radioactive elements, approximately 4½ billion years. It is generally agreed that the age of the earth is at least three billion years. It therefore follows that the amount of uranium now in the earth is about two-thirds the amount present when the earth was formed. In other words, only about one-third of the original amount of uranium has disintegrated into other elements.

The half-life of radium is about 1600 years. That is to say, one-half of a lump of radium (say, one gram of it) disintegrates in 1600 years; one-half the remainder (½ gram) disintegrates in 1600 years; one-half the remainder (¼ gram) disintegrates in the next 1600 years; and so on indefinitely.

Uses of Radium. Radium is used in the treatment of cancer. Its radiations penetrate human tissue and attack malignant growths. However, radon, a gaseous decay product of radium, is usually preferred for this work. Radon gas, the

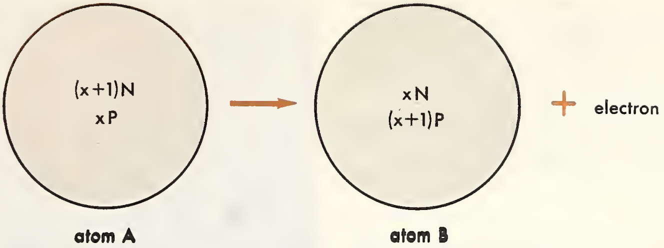


Fig. 19-8. Radioactive disintegration. A neutron in atom A changes to a proton and an electron. The electron (beta particle) is ejected, thereby forming a new atom B.

heaviest of all gases—seven times denser than air—is pumped into thin-walled glass tubes which are sealed and applied to the diseased tissue. Radon has a very short half-life of only about four days and, for this reason, is more radioactive than radium. However, some radioisotopes made in a reactor are more suitable for therapeutic purposes than radium and radon in the treatment of cancer.

Radium compounds are also used in making luminous paint. A tiny amount of a radium compound (only a few cents worth) is added to paint which contains a fluorescent substance such as zinc sulfide. Radiations from the radium cause the zinc sulfide to fluoresce so that if the paint is applied to the dials of watches, clocks, compasses, or airplane instruments they can be seen in the dark.

Some Geologic Applications of Radiations. Radioactive substances in the earth's crust act as time clocks and give reliable information concerning the age of the earth. A uranium ore always contains some lead, which is a decay product of the uranium. The amount of lead in a piece of ore increases steadily with the length of time from the formation of the ore to the present day. The rate at which uranium disintegrates is known, and therefore the age of the rock can be computed from the relative weights of lead and uranium in the ore. Some rocks examined in this way have been found to be at least two and a half billion years old.

Then again every radioactive rock generates heat as it disintegrates. Every gram of radium, for example, emits millions of alpha particles per second. These particles are stopped by surrounding material so that their energy of motion is converted into heat. From a gram of radium heat is evolved at the rate of about 100 calories per hour, and it can be shown that the heat liberated during its complete disintegration would amount to almost two billion (2,000,000,000) calories. Some geologists believe that the earth is maintained at its present temperature by the radioactive changes in rocks, and that, without this source of heat, the earth would be too cold to support life.

Atomic Bullets from Radium. Rutherford hit upon the clever idea of using alpha particles shot off by radium to investigate the structure of atoms. By using alpha particles as "bullets" he hoped to split atoms and, in this way, to learn of their structure. The effectiveness of a bullet depends upon its mass and speed. And the fantastically high speeds of the alpha particles (great enough to encircle the earth at the Equator in less than one second) seemed to make them ideal "bullets" for bombarding atoms.

Rutherford bombarded various elements with alpha particles from a radioactive source. He noticed that when light elements such as nitrogen were bombarded, positively charged particles were invariably ejected from the bombarded nuclei. He therefore concluded that positive particles were an essential ingredient

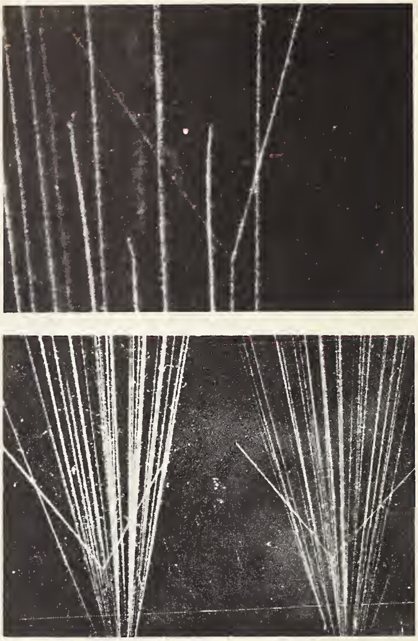


Fig. 19-9. The upper picture shows alpha particles streaming through a cloud chamber. The collision is between an alpha particle and a hydrogen nucleus. The light hydrogen nucleus is deflected to the left, but the path of the heavier alpha particle is deflected only slightly to the right.

In the lower picture an alpha particle collides with a helium nucleus. These particles have the same mass and appear to be deflected equally.

of every nucleus. He appropriately called them ***protons,*** a word derived from the Greek "protos" meaning ***first,*** the original particle in all atoms. By a suitable device (a cloud chamber), the tracks of the particles were photographed. From the millions of particles ejected by the source, only an occasional bulls'-eye was scored. When a nucleus target was hit, the alpha particle was sometimes deflected in one direction and the nucleus itself in another. Such a situation is shown in Fig. 19-9. Most alpha particles passed through the bombarded atoms without a collision, and from this observation it was concluded that atoms are mostly empty space.

The phenomena of radioactivity shed much light on the structure of atoms. And what of the energy released by radioactive atoms? Where does it come from? Scientists now know that this energy comes from matter. Radium has been converting mass into energy since the earth was formed. Is it possible to convert mass into energy on a large scale? This important question is answered in the Chapter 33.

THE PERIODIC CHART

We have already seen how the periodic chart is used to tell us the structure of the atoms. It also tells us about the properties of the elements.

You will notice that the elements are divided into groups. In each of these groups the elements have the same number of electrons in the outermost shell. Since the electrons in the outermost shells are the ones which enter into chemical reaction, then elements with the same number of electrons in the outer shells will behave in a similar manner.

In group IA lithium has one electron in the outer shell, and so has cesium. We will then expect them to react in a similar way and form compounds like LiCl and CsCl.

In group IIA we can expect calcium and radium to have similar properties, since they both have two electrons in the outer shell.

These family resemblances help us to remember the properties of the elements.

When elements react, they do so in such a way as to complete their outer shells of electrons. ("For any atom other than hydrogen or helium, the outer energy level will hold 8 electrons, arranged only in the s and p orbitals, when it forms

Sodium atom
$1s^2\ 2s^2\ 2p^6\ 3s^1$

Chlorine atom
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Sodium ion Na^+
$1s^2\ 2s^2\ 2p^6$

Chlorine ion Cl^-
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Fig. 19-10. Sodium and chlorine react to form sodium chloride.

simple compounds"). Atoms can do this in two ways, by giving away electrons, or by sharing electrons. Therefore there are two ways in which chemical bonds may be formed.

How Compounds are Formed by Giving Away Electrons: *Electrovalent Bonds.* When sodium reacts with chlorine it does so in such a way as to give both elements in the reaction a more suitable arrangement of electrons. The sodium atom, before it reacts, has one electron in its outer shell; the chlorine atom, before it reacts, has seven electrons in its outer shell. When they react, the sodium atom gives one electron to the chlorine atom. In this way both have eight electrons in their outer shells, which is a suitable arrangement.

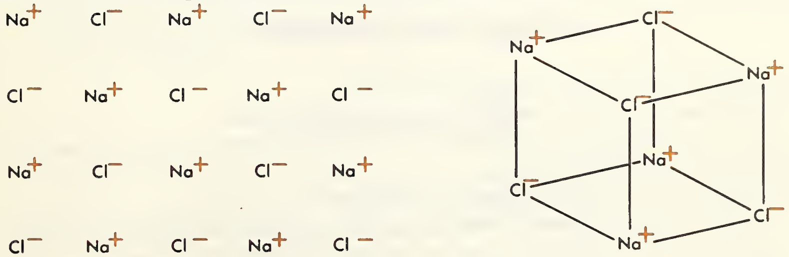
All salts contain charged particles similar to the type found in sodium chloride. Notice that the Na atom has lost an electron, and so has one extra positive charge: it is now a positive ion. The chlorine has gained an extra electron. It now has one extra negative charge, and is a negative ion. The resulting sodium chloride crystal is made up of these positive and negative ions held in position by the electrostatic forces between them which form a three-dimensional lattice with an ion at each corner of a cube.

We call this type of bond an electrovalent bond.

How Compounds are Formed by Sharing Electrons: Covalent Bonds. Many atoms do not give away electrons to other atoms. Instead they only share them thereby forming covalent bonds.

Hydrogen forms a covalent bond when it combines with oxygen to form a molecule of water. The hydrogen atom has only one electron in the 1s orbital and, you recall, that this orbital can hold two electrons. Then again an oxygen atom has only one electron in the $2p_y$ orbital and one electron in the $2p_z$ orbital, and each of these orbitals can hold two electrons. Two hydrogen atoms can therefore combine with one oxygen atom and by overlapping the hydrogen orbitals with the oxygen orbitals can satisfy the requirements of the 1s orbital of the hydrogen atoms and the $2p_y$ and $2p_z$ orbitals of the oxygen atom. Since the $2p_y$ and $2p_z$ axes are at right angles to each other we would expect the angle between the two hydrogen-oxygen bonds to be 90°. In experiments it is found that actually the bond is 104° which is quite close to the 90° predicted. This is shown in Fig. 19-12. ***The covalent bond then involves the sharing of a pair of electrons.***

A covalent bond is often shown by joining the atoms with a straight line

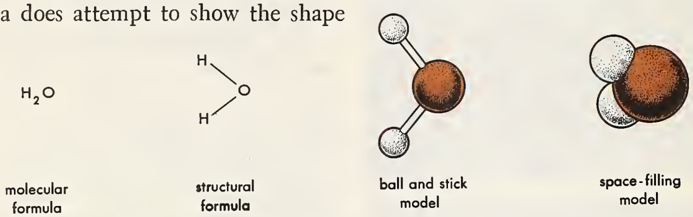


Sodium chloride in two dimensions

Sodium chloride in three dimensions, a cubic arrangement

Fig. 19-11. Sodium ions and chloride ions form a crystal structure.

(see Fig. 19-12 for the diagram of the water molecule). Such formulae are called structural formulae in contrast to the molecular formula of water which is simply stated as H_2O. The structural formula does attempt to show the shape of the molecule, but since it is represented on a flat surface one should remember that the molecule is three-dimensional and that only two dimensions can be represented on a flat surface.



molecular formula — structural formula — ball and stick model — space-filling model

Fig. 19-12. The water molecule. The angle between the bonds is just slightly greater than the 90° predicted. The space-filling model most nearly represents the molecule.

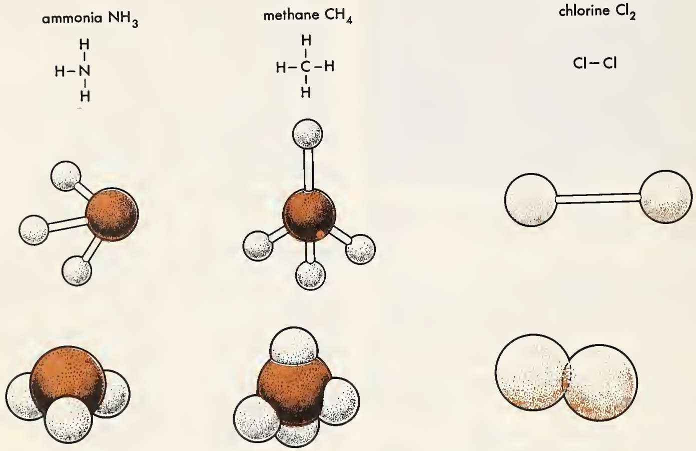


Figure 19-13. Some molecules containing only covalent bonds.

Things to Remember

An ***electron*** is a particle of negative electricity.

The ***nucleus*** of an atom consists of protons and neutrons.

The ***atomic weight of an element*** is the number of protons and neutrons in the nucleus of one of its atoms.

A ***proton*** carries a positive charge of electricity.

The ***weight of an electron*** is about $\frac{1}{1800}$ the weight of a proton or neutron.

Isotopes are atoms of the same element but with different atomic weights.

Natural uranium consists of 2 isotopes, U-238 (plentiful) and U-235 (rare).

U-235 is ***fissionable*** by slow neutrons.

Alpha rays are positively charged particles.

Beta rays are electrons.

Gamma rays are similar to X rays.

In ***radioactivity,*** alpha, beta, and gamma rays are emitted.

The ***half-life of a radioactive element*** is the time required for half of its atoms to disintegrate.

Questions

GROUP A

1. What is (*a*) an electron, (*b*) a proton? Compare the weights of a proton and an electron.
2. The nucleus of an atom contains 11 protons and 12 neutrons. What is its atomic weight?
3. What are isotopes of an element? Name the 3 isotopes of hydrogen. What are their atomic weights?
4. Name the two isotopes in natural uranium. In what proportion are they present?
5. What was the particular contribution of the Curies to radioactivity?
6. Name some of the uses of radium.

GROUP B

7. The atomic weight of an atom is 25, and there are 12 protons in the nucleus. How many neutrons are there in the nucleus? Draw a diagram of the atom.
8. What is meant by the term ***stable structure?*** Illustrate your answer by reference to the structures of atoms of helium and neon.
9. The atomic weights of the two isotopes of carbon are 12 and 13. Draw atomic diagrams of these isotopes.
10. What are alpha, beta, and gamma rays? Explain.
11. Explain why a new element is formed if a radioactive atom ejects a beta particle.
12. Explain why the concept of ***half-life*** is more useful in radioactivity than the concept of ***whole life.***
13. Some geologists state that without radioactivity the earth would be too cold to support life. Explain what this means.
14. What did Rutherford discover by bombarding various elements with alpha particles? Explain.

Things to Do

Alpha particles from a wrist watch · Look at the luminous dial of a wrist watch or a compass in a room that is totally dark. Examine one of the numerals closely through a powerful magnifying glass. When your eyes have become used to the darkness you will note that the numeral is not illuminated by a steady glow of light. Instead, light is emitted in flashes.

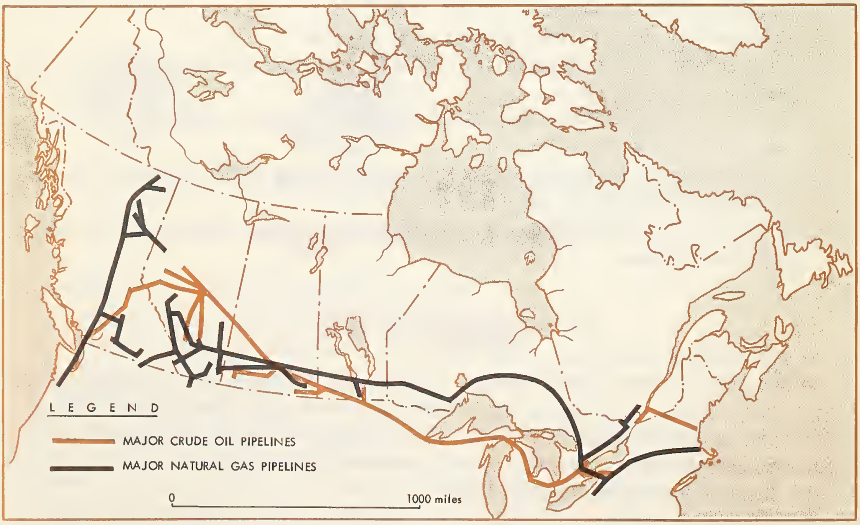
The flashes of light are scintillations emitted every time an alpha particle strikes a molecule of zinc sulfide.

20

FUELS—SOLID, LIQUID AND GASEOUS

The advance of technology in the world has been based upon the supply of energy available. The early technological development of Great Britain, western Europe, and the United States depended to a great extent upon their large supplies of coal. With this coal they could develop industries. Today we have many fuels available, and, in contrast to the nineteenth century when industry had to be brought to the fuel, the fuel can now be transported to the centers of industry by

Fig. 20-1. Today fuel is transported to the centres of industry. Crude oil and natural gas are Canada's major energy source.



Biology-The Study of Life

LOOKING AHEAD

Man has always been aware of life and living things. His first interest in plants and animals was in their usefulness to him in his struggle to survive (or as enemies that might prey upon him). Plant and animal products provided him with food and materials from which he could fashion clothing, tools and weapons which would make him more effective in providing for his needs.

Earliest man, for lack of knowledge and the means of being precise in his observations endowed all creatures in his environment, including himself, with an aura of mystery and tried to explain them in terms of the supernatural. He had a vast array of gods and demons, who, he believed often just toyed with him and his destiny.

As knowledge grew and new methods of study were developed, the environment became less and less mysterious and progressively less fearsome. Man came to understand the creatures around him and to use them to his advantage or at least to control them.

Out of the understandings gained about our environment have come the fields of study such as medicine, agriculture, genetics and many others upon which we so greatly depend today.

Our knowledge of life and living things is by no means complete. Many exciting things are still coming to light on the frontiers of research. There are many questions to which we do not yet know the answers. It is hoped that in this unit you will gain some knowledge concerning life, the structures associated with life and the processes that together constitute life.

← *Investigating the effect of colored lights on photosynthesis (John Krestic)*

37

THE LIVING CELL

As WE LOOK about us we must be impressed with the tremendous variety of living forms that exist. They consist of the tiniest insect to the massive whale or elephant and the simple unicellular plants living in water in the form of slime to the massive redwood trees which tower more than three hundred feet in the air. In addition to these visible creatures there is a vast world of microscopic forms, of which most of us are unaware except for the effects they have upon us or our belongings. What is it about these seemingly greatly different beings that makes them living? Is there something that they all have in common? These are not new questions. They have been asked many times during the past and the answers we have today are not at all complete.

The Microscope An instrument which has greatly aided the biologist in his quest for knowledge is the microscope. It consists of a combination of magnifying lenses. As far as we know the first microscope was produced by J. and Z. Janssen in 1590. They were lens-makers and while trying to improve their technique for polishing lenses they inadvertently combined two of them and discovered that increased magnification was possible.

Anton van Leeuwenhoek (1632-1723) of Holland is given credit for having produced the instrument which is familiar to us today. He was a ribbon clerk but had a tremendous curiosity concerning the little creatures which he found in rain water. Because of the technique used for mounting specimens Leeuwenhoek had to make a new microscope each time he wished to study another animal. In this way he made something over a hundred microscopes, improving on them each time. He was able eventually to study unicellular animals (protozoa) and describe them in detail.

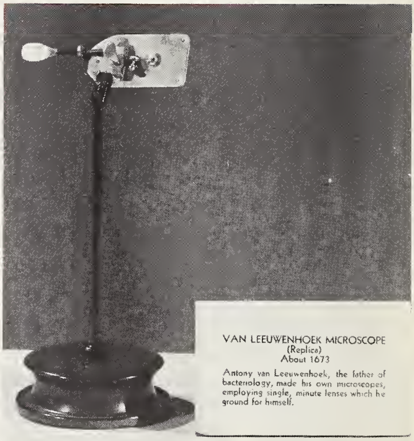

VAN LEEUWENHOEK MICROSCOPE
(Replica)
About 1673
Antony van Leeuwenhoek, the father of bacteriology, made his own microscopes, employing single, minute lenses which he ground for himself.

Fig. 37-1. Leeuwenhoek's Microscope.

Leeuwenhoek's microscope has been improved upon many times and the result is the compound microscope so common to biology laboratories today. This instru-

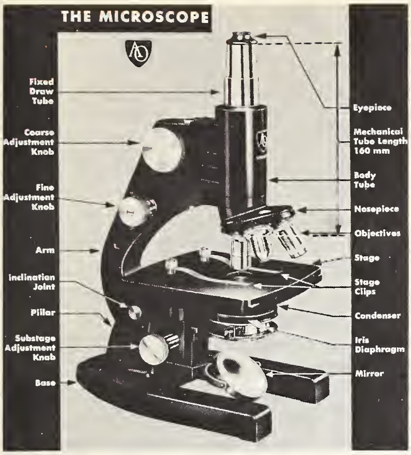


Fig. 37-2. A Compound Microscope.

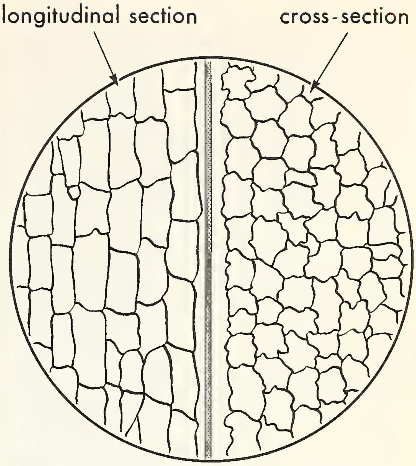


Fig. 37-3. Cork tissue seen by Hooke.

ment however has limitations. For greater magnification (up to 2,000,000 diameters) scientists use the electron microscope.

The Cell Principle. Today no one doubts the existence of cells. However, this has not always been so. It took the work and thought of many men to provide us with the knowledge we have today.

In 1665, Robert Hooke, curator of the Royal Society of London, while examining a slice of cork under the microscope saw empty spaces surrounded by rather thick walls. These structures reminded him of the monks' cells in the monasteries, which were common then, and thus named these structures "cells". The term has been used ever since. The structures which he saw were dead. The living contents had disintegrated and thus the cells were empty.

It was not until 1772 that cell contents were observed. Corti, an Italian, observed a watery material in plant cells and called it "cell sap".

In 1831, Robert Brown, a British botanist observed and described dense regions in the cell sap. These came to be known as nuclei.

It was by no means common knowledge that all living things were composed of cells. In 1839, Matthias Schleiden, a German botanist and Theodor Schwann, a zoologist, jointly reported that they had observed that all tissues had basically the same pattern. The theory which they proposed was known as the Cell Theory. A great deal of research has since been carried out and no evidence to refute their findings has been found. The theory has been expanded to become the Cell Principle, which quite simply states:

(i) all plants and animals are made up of cells,
(ii) cells are the units of function of all living things,
(iii) protoplasm is the essential living matter of every cell, and
(iv) new cells develop only from parent cells.

Protoplasm. The entire living content of the cell is composed of protoplasm and is often referred to as the protoplast. Protoplasm is the substance of life. No living thing exists that is not composed of protoplasm. In his search for knowledge man has thoroughly examined and analyzed this material.

Protoplasm has been observed to be a jelly-like material. Its consistency is not constant. At times it may be quite firm while at others it is decidedly watery.

Protoplasm is a mixture of substances. Water is most abundant, making up about 90% of the protoplasm in such animals as the jelly-fish. Suspended and dissolved in this water in varying amounts will be found carbohydrates (sugars), proteins and fats. Elements found in largest amounts are oxygen, carbon, hydrogen and nitrogen.

All the activities which we associate with life and the act of living are carried out by and usually within the protoplasm. Nutrition which involves the getting and using of food; metabolism the process of building up new material and the release of energy; locomotion, the ability to move about; and responsiveness, the ability to respond to stimulation are some of the activities which are performed by protoplasm. Its very ability to do these things makes protoplasm a living substance. Indeed, it must maintain some degree of constant activity or it will die and disintegrate.

The Cell. A cell is a rather complex unit of material. All the activities mentioned above must be performed by this unit. Hence it is referred to as the unit of function as well as the unit of structure.

The outer limiting structure of the cell is the plasma membrane which is a continuation of the living material or protoplasm. This membrane regulates the passage of materials both in and out of the cell.

Generally, near the center of the cell is a more dense region. This region is known as the nucleus. It has been found that the nucleus controls all the vital activities of the cell.

The watery material filling the remainder of the cell is the cytoplasm. It contains protoplasmic structures and other particles which are called inclusions. The protoplasmic structures are involved in or are the sites at which the various processes occur. The functions performed by a given cell are limited by the structure of the cell.

Plant Cell. Certain distinctive characteristics make it possible to recognize plant cells. The structure which is found in nearly all plant cells is the cell wall. This wall consists of cellulose (a carbohydrate) produced by the cell and deposited on the outer surface of the plasma membrane. Its function is to protect the cell from damage, and to provide support.

The cell membrane, as mentioned earlier, regulates the passage of materials in and out of the cell. Some materials are allowed to pass while others are not. A membrane such as this is said to be semipermeable. Water passes through a semipermeable membrane by the process of osmosis. Other materials, such as gases and foods, also pass through the membrane but their passage is by diffusion.

Cytoplasm, as described earlier, is that portion of the cell content exclusive of the nucleus. In some cells it has a granular appearance due to the presence of plastids and other dispersed solid particles. The most conspicuous granule in the plant cell is the chloroplast. It is green in color because it contains the pigment chlorophyll. Other pigments may also be present in the form of plastids called chromoplasts. These are common in cells found in such structures as the petals of flowers.

Centrally located in the cell and more dense in appearance is a body called the nucleus. This structure contains the chromatin, the material which influences hereditary characteristics. Experimentation in which the nucleus was removed from a living cell has shown that the nucleus regulates most of the activities of the cell, especially those in the building up of protoplasm.

Included in the cytoplasm are one or more spaces, called vacuoles. In plants these serve as storage places for dissolved waste materials. As the cell matures the vacuole may almost completely fill the cell. Only a film of cytoplasm covers the inner surface of the plasma membrane.

A plant which may easily be obtained and which displays a typical cell structure

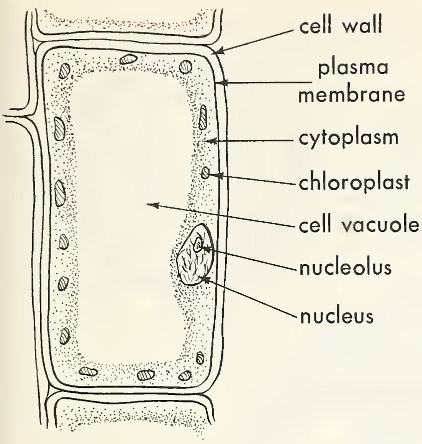


Fig. 37-4. Typical Plant Cell.

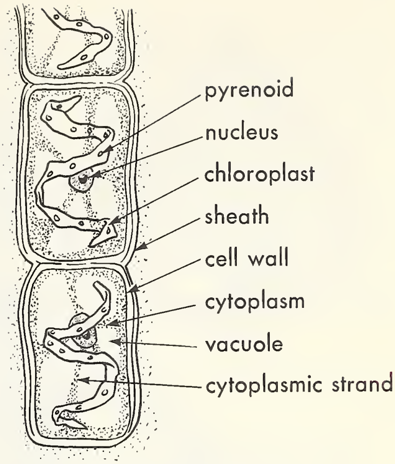


Fig. 37-5. Spirogyra.

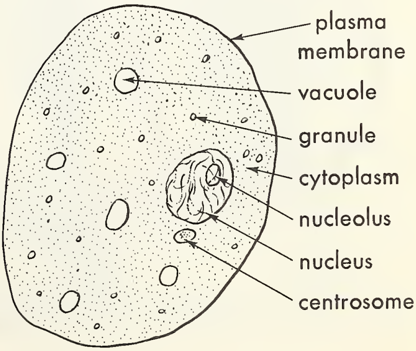
is *Spirogyra*. The slippery green scum often found on the surface of ponds is *Spirogyra*. It is a simple plant in which the cells remain attached to one another to form threads (filaments). All the cells which make up filament of *Spirogyra* are the same so by examining one cell we may become familiar with the structures of a typical plant cell.

On the outer surface of each filament is a slippery jelly-like material called a sheath. Surrounding each cell is a cell wall composed of cellulose. It is this cell wall which provides rigidity and shape to the cell. Within the cell the most obvious structure is the chloroplast. It is like a spiral ribbon that is embedded in the cytoplasm. Circular structures called pyrenoids occur at intervals along its length. The chloroplast is involved in photosynthesis (to be discussed later) while the pyrenoids are thought to be involved in the conversion of sugars produced by photosynthesis to starches for storage. The nucleus is surrounded by cytoplasm and is suspended by strands in the approximate center of the cell. The spaces within the cell make up the cell vacuoles.

Animal Cell. Basically an animal cell has the same parts as a plant cell. It possesses a nucleus, cytoplasm, plasma membrane and vacuoles. There are differences however with respect to some of the parts. An animal cell never has a cell wall nor chloroplasts. Some unicellular animals may have a protein deposit on the plasma membrane called a pellicle. Animal cells are more flexible than plant cells, and thus animal cells may readily change shape.

The vacuoles in animal cells are generally smaller and more numerous than in plants. In some of the protozoa, special vacuoles whose function is to pump excess

Fig. 37-6. Typical Animal Cell.



water out of the cell, may be found. These are called contractile vacuoles. Other vacuoles may contain food particles. It is in these vacuoles that digestion takes place. They are called food vacuoles.

Near the nucleus in most animal cells is a structure called the centrosome. It divides first during cell division and seems to be involved in the whole process of cell reproduction.

Cell Variability. Multicellular organisms consist of many cells. As the number of cells in an organism increases the individual cells tend to become dependent on one another. Functions such as digestion and locomotion are performed by groups of special cells. This division of labor, leading to specialization of cells, in turn results in the change of shape and general structure of the cell itself. We find therefore in highly complex animals and plants many kinds of cells such as muscle cells, nerve cells and skin cells.

Things to Remember

The ***microscope*** is a combination of lenses which makes it possible to magnify, and make visible, objects which cannot ordinarily be seen with the naked eye.

Cells are the units of which all living things consist.

Protoplasm is the substance of life and makes up the entire living contents of the cell.

The ***plasma membrane*** is the outer limit of the protoplasm and regulates the passage of materials in and out of the cell.

The ***cell wall*** consists of cellulose and is a structure found only in plant cells.

The ***chloroplast*** contains chlorophyll and is the structure in which photosynthesis occurs.

A ***nucleus*** is a dense region, usually near the center of the cell, that carries the determiners of heredity.

Pellicle is a protein deposit on the outer surface of some animal cells.

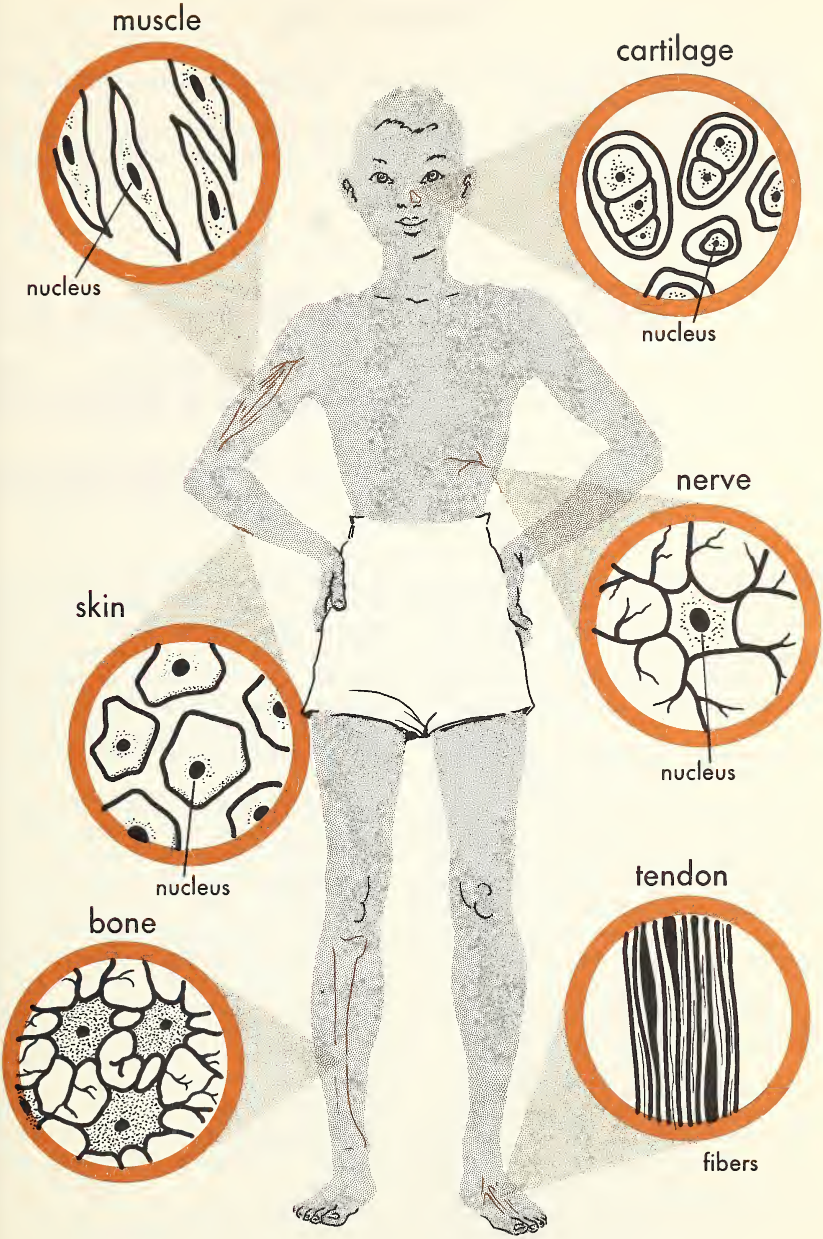
Questions

GROUP A

1. What did the Janssens contribute to the study of living things?
2. How did Leeuwenhoek happen to improve on the microscope so greatly?
3. Why did Robert Hooke name the structures which he saw ‘cells’?
4. Who discovered the cell principle?
5. List the points of the cell principle.

GROUP B

6. Describe the appearance of protoplasm.
7. What is a life process? List some of the life processes.
8. What is meant by a semipermeable membrane? What is its function in a cell?
9. How may the function of the nucleus be determined? What is its function in the cell?
10. How does an animal cell differ from a plant cell?
11. What is the function of the contractile vacuole in some of the protozoa?


muscle
nucleus
cartilage
nucleus
nerve
nucleus
skin
nucleus
bone
tendon
fibers

Things to Do

Models of cells. Using either modelling clay or plaster of Paris construct models of both plant and animal cells.

Using the technique described on page 70 make permanent models by making plaster casts of them. These models can be made more meaningful if the parts are outlined or painted in.

38

CLASSIFICATION OF PLANTS AND ANIMALS

MORE THAN a million different kinds of organisms inhabit the earth. They live all about us, in the air, on the surface of the earth, in the water and in the soil. It is impossible to know the name of each one of these. Plants and animals may be grouped into broad categories. All members of a given category resemble one another.

Common Names. Wherever man has gone on earth, he has shown an intense interest in the living things around him. To be able to identify these organisms he has assigned names to them. Often, however, the same organism was given a different name in different localities, e.g. Flicker, Yellow Head, Yellow Headed Flicker and Yellow-headed Woodpecker all refer to the same bird. Sometimes the opposite was true. The same name was used to indicate two very different organisms, e.g. the term gopher as we know it refers to a rodent which lives in burrows in the ground yet in Florida it refers to a kind of turtle.

It was quite impossible for scientists to communicate with one another since they simply did not use the same names. To make communication possible it was necessary to devise a system which could be used the world over.

Linnaean System. In the year 1753, Carolus Linnaeus, a Swedish botanist, proposed a system which because of its simplicity became universally accepted by scientists.

One of the difficulties of previous systems was that they always used the language of the author. This aroused national loyalties and for one reason or another these systems were not acceptable. Linnaeus suggested Latin as the language to be used in his system. His reasons for suggesting Latin were that:

(i) it was the language of scholars and thus accepted by them;
(ii) it was a classical language and thus would not change through daily use; and
(iii) it permitted precise description.

Linnaeus suggested that all organisms could be grouped according to structure; all organisms with similar structures were placed into the same category. On this basis he suggested that all organisms were either plants or animals. These two categories he called ***kingdoms.***

Not all plants and animals are the same.

It was necessary to subdivide each kingdom into smaller groups called ***phyla.*** Much diversity still existed within each phylum so further subdivision was necessary. This subdividing of groups continued until an organism could be identified specifically. The additional categories that were needed for specific identification were ***class, order, family, genus*** and ***species.*** It must be noted that each successive group contains fewer members but there also are fewer differences among members of the group.

The following table illustrates how various organisms may fit into this system of classification.

Kingdom	Animal	Animal	Animal	Animal	Plant
Phylum	Chordate	Chordate	Chordate	Arthropod	Tracheophyte
Class	Mammal	Mammal	Amphibian	Insect	Angiosperm
Order	Carnivora	Primate	Anura	Orthoptera	Campanulales
Family	Canidae	Hominidae	Ranidae	Locustidae	Compositae
Genus	Canis	Homo	Rana	Schistocerca	Taraxacum
Species	familiaris	sapiens	pipiens	americana	officinale
	Dog	Man	Frog	Grasshopper	Dandelion

The last two categories (genus and species) together constitute the scientific name of an organism. From the above table we see that man's scientific name would be ***Homo sapiens,*** that of the dog ***Canis familiaris*** and of the common leopard frog ***Rana pipiens.***

The Modern (so-called) System. As more knowledge about organisms came to light, it became apparent that similarity of structure is not the only basis for classifying organisms. It may not even be the most important one. It has been found that cellular complexity and the chemical activities carried on within the cell are additional criteria which make the placing of organisms much more accurate.

Using these criteria it was found that two kingdoms were not enough. It forced scientists to put organisms which were not really related into the same group. To overcome this, it was suggested that there be four kingdoms; Monera, Protista, Plantae and Animalia.

Kingdom Monera contains all those organisms which are unicellular but whose cell structure is not highly developed. The nucleus is not enclosed in a cell membrane and the nuclear material is dispersed throughout the cell. Such organisms as bacteria and blue-green algae are monera.

Kingdom Protista contains all the remaining unicellular organisms. These, however, have clearly defined nuclei enclosed in a nuclear membrane. Included in this kingdom are organisms which at one time were thought to be quite different kingdoms. Such organisms as ***Amoeba*** and ***Paramecium*** which at one time were considered as animals and ***Spirogyra, Ulothrix,*** bread mold, mushrooms, once considered to be plant are now considered to be protists.

Kingdom Animalia includes all the multicellular animals. These all display cell differentiation into tissues and even organs. Reproduction is rather complex involving complex multicellular organs. Development into an adult passes through an embryonic or larval stage. Members of this kingdom are diverse, ranging from the relatively simple sponge and ***Hydra*** *through* the earthworm, tapeworm, molusks, and insects to the very complex organism known as man.

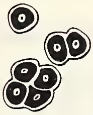
KINGDOM MONERA

bacteria

Simple organisms, unicellular, no distinct nucleus, no nuclear membrane.

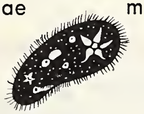
Examples: bacteria, blue-green algae

KINGDOM PROTISTA


algae

molds

ameba


paramecium

vorticella

Simple organisms, unicellular or colonial, distinct nucleus with nuclear membrane.

Examples: green algae, molds, Amoeba, Paramecium

KINGDOM PLANTAE

moss plant

liverwort

Bryophytes

Simple stems and leaves; no roots or flowers.

Examples: mosses and liverworts

ferns

horsetails

corn plant

bean

Tracheophytes

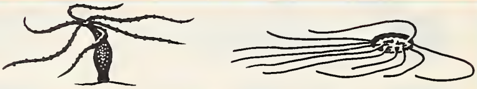
True roots stems and leaves with a well developed vascular system.

Examples: ferns, horsetails, trees, beans, grains, grasses

ANIMAL KINGDOM

Porifera
Simple many celled animal
Examples: sponges

Coelenterates
Animals with body cavity and tissues
Examples: hydra, jellyfish



Worms
Long, slender bodies.
Some are segmented
Examples: earthworm, tapeworm

Echinoderms
Spiny-skinned animals
Examples: starfish, sea urchin

Mollusks
Soft-bodied animals, usually with shells
Examples: snail, clam

Arthropods
Animals with jointed legs and segmented bodies
Examples: insects, spiders, crabs

Chordates
Animals with internal skeletons and usually with backbones
Examples: fish, frog, bird, reptile, man

Things to Remember

Common names are those given to organisms by people living in a particular locality. The same name may be used for different organisms, or the same organism could have a different name.

Carolus Linnaeus proposed the classification system based on similarity of structure.

Latin was the language of scholars at the time of Linnaeus.

The ***scientific name*** of any organism consists of the genus and species.

In the current system there are four kingdoms: ***Monera, Protista, Plantae*** and ***Animalia.***

Questions

GROUP A

1. What is a common name?
2. Why was it impossible for scientists to communicate?
3. State the three advantages of Latin over other languages for use in a system of classification.
4. The grouping of organisms in the Linnaean system was on what basis?

GROUP B

5. List the categories or groups that were suggested by Linnaeus.
6. Give the complete classification for man. What is man's scientific name?
7. List the four kingdoms of the current system of classification and state the main characteristic of each together with an example.

Things to Do

A Collection of Organisms. You may wish to make a collection of insects or of plants or some other set of organisms. Consult a guide for the proper collecting techniques. Be sure to mount each specimen carefully and identify it according to the system of classification.

The kingdom Plantae includes a ***wide variety*** of organisms.

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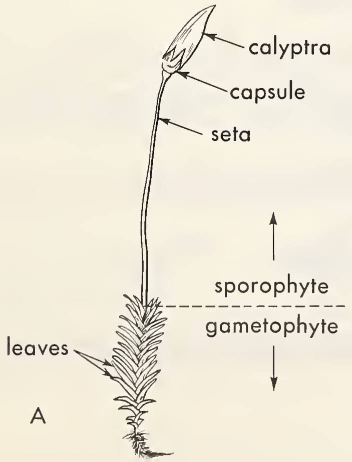
PLANTS

The kingdom plantae includes a wide variety of organisms. Although all are multicellular, not all of them are equally complex.

The simplest of the plants is the group which includes the mosses. These do not have root systems nor do they have true leaves and stems. There is little internal cell specialization. Because these organisms are really quite simple they must still depend on water to a large extent. Since they are unable to absorb water readily from soil, we find these plants growing in shady moist areas or in swampy regions.

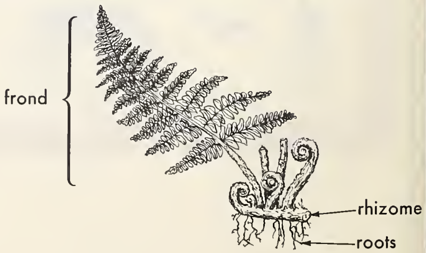
Fig. 39-1. Diagram of a moss plant.



Next in complexity is the group of plants which includes the ferns, examples of which are often found in homes. These plants have true roots, stems and leaves and have a fairly well developed system of specialized cells to transport materials throughout the organism (Such a system is known as a vascular system.) Ferns do not have flowers for purposes of reproduction. At one time in the history of the earth this was the predominant form of plant. Some specimens grew as high as thirty feet. Accumulation of these plants occurred and through the ages chemical changes taking place produced great coal deposits.

The most complex plants are the seed producing plants. These have all the structures mentioned in connection with ferns but have special structures for producing seeds as well. Some of these produce seeds in cones which leave the seeds exposed. Most of them, however,

Fig. 39-2. Diagram of a fern.



produce flowers from which the seeds form and in which the seed is protected by a structure called the fruit. Since these are abundant and especially sought after for gardens we will spend some time discussing flowering plants in detail.

Every flowering plant consists of four different organs. (An organ is a group of tissues together performing a particular function.) These organs are adaptations which make it possible for the plant to live and to survive in a particular kind of environment.

The Root. The root is that part of the plant which is found below the surface of the soil in which it is growing. Two types of root systems exist:

(i) Tap root. This system consists of a single fleshy central root with numerous small secondary roots projecting from the tap root. E.g. carrot, sugar beet, etc.

(ii) Fibrous root. A tangled mass of roots, all approximately the same size, make up a fibrous root system. This system is typical of the grasses which live in dry regions and need an extensive system for gathering water and minerals.

Roots generally have three functions:

(i) Anchorage. Plants must remain in one place. Without a root system the wind would be able to move plants about quite freely.

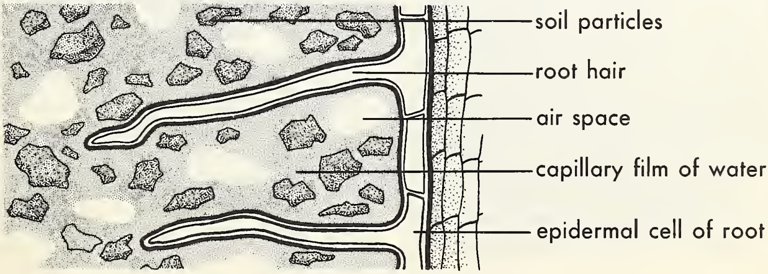
(ii) Absorption of water and minerals. Water is necessary for the process of food making. The only source of water available to land plants is the soil and so the root plays a very important role.

(iii) Food storage. In some plants surplus food is transported to the root where it is stored. This is true of such plants as carrots, turnips and sugar beets.

The most important function of the root is absorption. This occurs mainly through a special structure known as a root hair. The root hair is an extension of an epidermal cell, not a structure in itself. Water enters the cell by osmosis.

The root of a flowering plant consists of a number of tissues each of which serves a special function. The outer layer of cells is the epidermis. It consists of closely packed cells often with a waterproof covering. The epidermis protects the inner tissues and also prevents the loss of moisture. Inside the epidermis is a mass of cells which is rather loosely packed. The region is the cortex. In most plants it serves as a place for storage. The remainder of the root is called the central cylinder. It contains the tissue whose special function is conducting materials to the rest of the plant. Two kinds of conducting tissue are present in the central cylinder. The thick-walled cells in the center are the xylem and conduct water and dissolved minerals upward in the plant. Small pockets of thin-walled cells lie between the xylem and the outer layer of cells of the central cylinder. These pockets are the phloem whose function

Fig. 39-3. Root hair in soil.



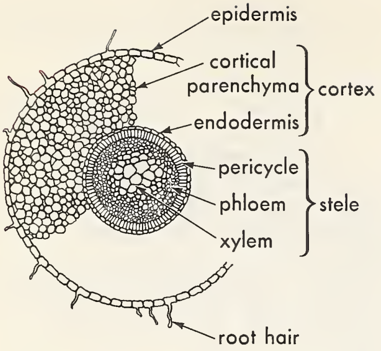


Fig. 39-4. X-section of root.

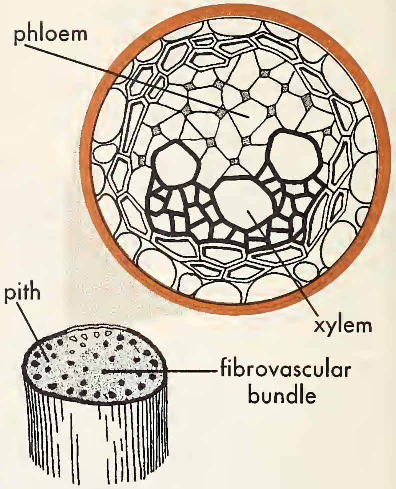


Fig. 39-5. X-section of corn stem.

it is to conduct food material from the leaves to the rest of the plant.

The Stem. The stem is that part of the plant above the ground except for the leaves and flowers. This is generally true but there are exceptions. Ferns for example have an underground stem as do tuberous plants like the potato.

Stems have several functions:

(i) To produce and display the leaves in such a way that they will receive maximum sunlight.

(ii) To conduct water and other materials from the roots to the leaves and from the leaves to the rest of the plant.

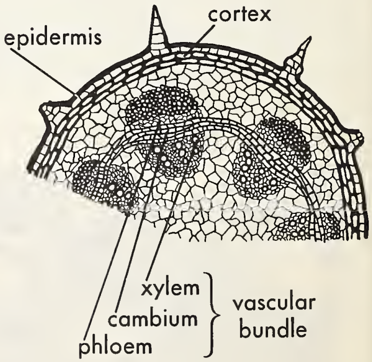
(iii) In some plants the stems may also serve as a storage place for surplus food. The potato is a good example of this. The tuber is an under ground stem and serves as a storage center for starch. Sugar cane is another example.

(iv) In young stems chlorophyll may be present and thus food manufacture may be carried on.

All stems have the same basic tissues. The arrangement of these tissues varies however. The conducting tissues, xylem and phloem, are bundled together to form structures called fibrovascular bundles. Stem type is based on the arrangement of these bundles. In stems of plants such as corn the bundles are scattered. Such plants are called monocots.

Many plants have stems in which the vascular bundles form a single ring. In addition to the xylem and phloem which have already been mentioned the vascular bundles of these plants have cambium. This is living tissue which divides rapidly

Fig. 39-6. X-section of sunflower stem.



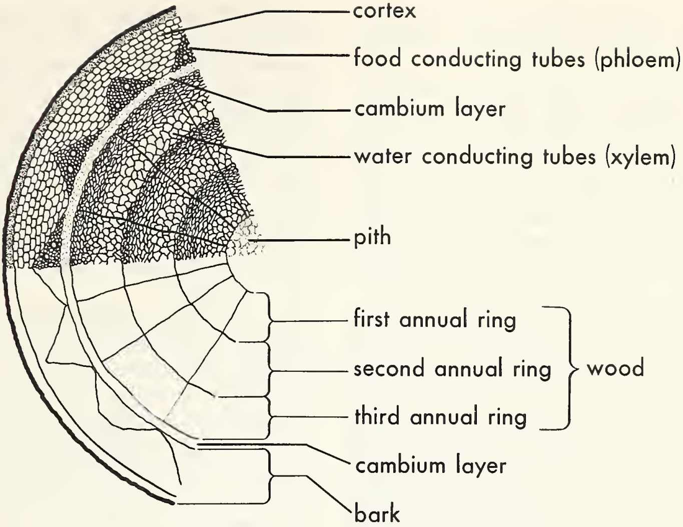


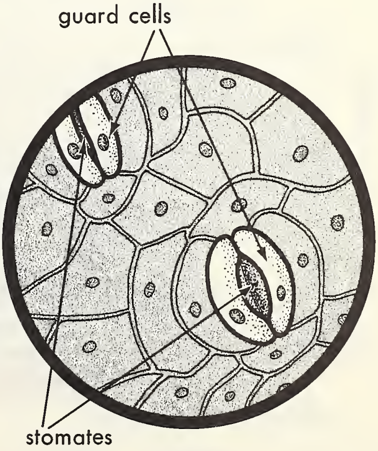
Fig. 39-7. X-section of woody stem.

to produce new xylem and phloem cells. It lies between the xylem and phloem tissues. This type of stem is said to be herbaceous.

The third arrangement of tissue is that in which the vascular bundles have merged to form complete rings. The cambium permits unlimited growth in thickness. Since these plants live and grow year after year, tissue seems to be laid down in rings. These are known as the annual rings and it is possible to determine the age of the plant by counting these. This type of stem is called woody.

The Leaf. The principal function of the leaves is to manufacture food. The process by which this occurs is known as photosynthesis. Before photosynthesis may take place an energy trapping pigment called chlorophyll must be present. Water absorbed by the roots is then split; the hydrogen and oxygen separate. The oxygen is of no further use in the process and is liberated into the atmosphere. The hydrogen, however, is combined with carbon dioxide from the atmosphere into a simple carbohydrate. Chemicals in the cell, called enzymes regulate this whole process. Two of these carbohydrates then unite with one another to produce a

Fig. 39-8. Enlarged drawing of stomates.



simple sugar, usually glucose ($C_6H_{12}O_6$). Glucose may be converted to starch for storage.

More water comes from the roots than can be used by the plant in photosynthesis. Gases must enter and leave the leaf. To permit this passage of substances leaves have small openings called stomates, usually on the underside of the leaf. The size of these openings is regulated by two bean-shaped cells called guard cells.

A leaf is not a simple structure. It consists of several layers of cells as well as bundles of specialized cells such as are found in vascular bundles. The top of the leaf is covered by the upper epidermis and the lower surface is covered by the lower epidermis. The cells that make up the layers are transparent. Each layer is one cell thick. The function of these is to protect the more delicate cells inside the leaf. The epidermis may have a waxy deposit called a cuticle. This makes the leaf waterproof.

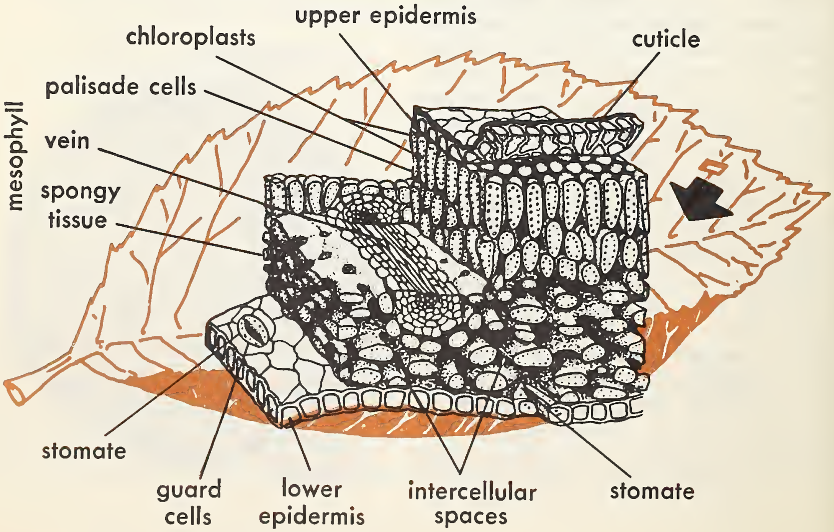
The cells between the upper and lower epidermis make up the tissue known as mesophyll. Usually the mesophyll is made up of two layers of cells. The upper layer consists of elongated cells (resemble an old fashioned log palisade). They are richly supplied with chloroplasts and it is here that most of the photosynthesis takes place. The rest of the mesophyll consists of rather loosely packed cells called spongy cells. It is through these cells that water loss occurs as well as most of the gas exchange. In the mesophyll are vascular bundles or veins made up of xylem (upper tissue) and phloem (lower tissue).

The Flower. Reproduction in the simple plants, since they live in water, is not a complicated matter. The water acts as the medium for bringing the reproductive cells together. In plants that live on land special problems exist. Before a seed may form two reproductive cells (sperm and ovum) must come together and unite. The flower is a specialized organ which makes it possible for this to happen.

A complete flower consists of four main parts. These parts are arranged in a ring. Beginning with the outer structure they are the sepals, the petals, the stamens and the pistils.

The sepals are the green leaf-like struc-

Fig. 39-9. X-section of leaf.



tures which protect the young bud. When the bud opens the sepals are spread apart. Together the sepals make up the calyx.

The petals are the colorful attractive parts of the flower. It is the petals which attract insects to the flower. The ring of petals form the corolla.

Just inside the petals is a ring of structures called the stamens. Each stamen consists of a slender stalk called the filament and a pollen bag called the anther. Within the anther many spores are formed which in turn produce pollen grains. It is the function of the pollen grains to produce and transport the sperms. The heavy outer coat prevents drying out of the cell even though it is in a dry environment.

The central structure of the flower is the pistil. The pistil consists of three parts, the stigma, style and ovary. The stigma is sticky and it is here that the pollen adheres when it makes contact. The style is simply the structure which joins the stigma to the ovary which contains one or more ovules. In each ovule a spore is formed which in turn produces an eight-celled structure called the embryo sac. Two of the cells are important in seed formation, the ovum and the endosperm nucleus.

Before fertilization (union of sperm and ovum) can take place the sperms must be delivered to the embryo sac within the ovary of the pistil. To accomplish this, once the pollen grain has adhered to the stigma, the pollen grain puts forth a growth known as the pollen tube. This grows down through the stigma and style and penetrates the embryo sac. The sperm nuclei (two of them) are passed into the embryo sac where one unites with the ovum and eventually produces the embryo (young plant). The other sperm unites with the endosperm nucleus and forms the nutrient material of the seed. The ovary may in some plants become greatly enlarged and becomes a fruit.

Fig. 39-10. Parts of Flower.

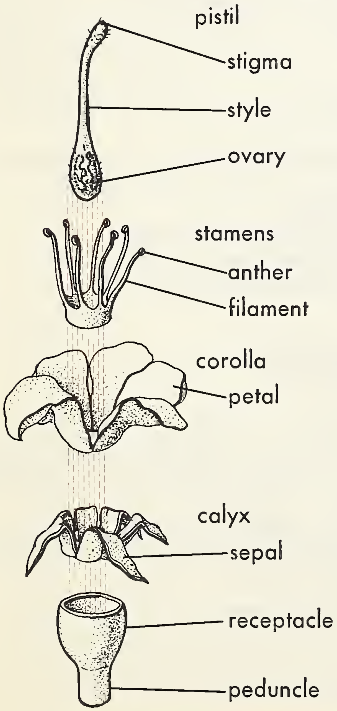
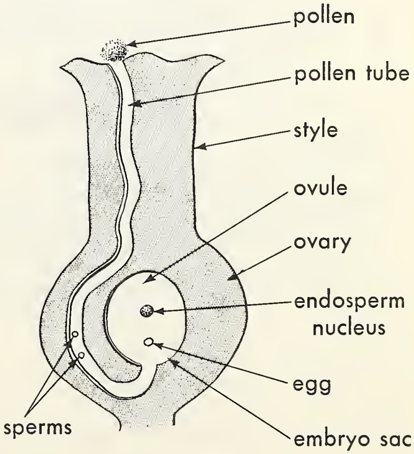


Fig. 39-11. Fertilization in a Flower.



Things to Remember

Mosses are the simplest of the plants. They require a moist environment to survive.

Ferns are the simplest plants to have true leaves, roots, and stems.

Flowers are special structures in seed formation.

The ***pollen grain*** produces the sperm.

The ***embryo sac,*** a dependent structure within the ovule of the flower, produces the ovum.

Fertilization occurs when two cells (sperm and ovum) unite to form a single cell from which a new organism grows.

Questions

GROUP A

1. Why must mosses remain close to a supply of water?
2. What is meant by a vascular system in plants?
3. What great group of plants resulted in the coal deposits found in various places in the world?
4. List the four organs that make up the body of a flowering plant.
5. List the parts of a flower and give the function of each part.

GROUP B

6. What is the function of root hairs?
7. By what process does water enter the plant?
8. What are the functions of a root?
9. What is the difference in the arrangement of tissue between a corn stem and a sunflower stem?
10. Explain what happens during photosynthesis.
11. What purpose does water serve in the reproduction of simple plants?
12. In flowering plants sperm transfer takes place in what manner?
13. Fertilization in flowering plants is said to be double. Explain this.

Things to Do

Flower structure. Secure a simple flower common in your area. (Sweet peas are abundant in some areas in the early autumn). Examine its various parts and make a drawing of the flower and label its parts.

If a variety of flowers is available, you may examine these and compare their structures. Are they all the same? Do they all have the same number and kinds of parts?

40

ANIMALS

ANIMALS, unlike most plants, do not have chlorophyll. Because of this, animals are unable to manufacture their own food, but most depend on green plants to produce all their food needs. The procuring of food is a major activity of all animals. Not all animals secure their food in the same manner. There are three relationships between animals based upon the manner in which food is acquired.

(i) Parasitism is the relationship between two living organisms in which one secures nourishment from the other, often causing harm. The animal that provides the nourishment is called the host. Such animals as the tapeworm, the body louse and the leech are parasites.

(ii) Mutualism is the relationship between two animals in which both members benefit. Some of the organisms have become so dependent on one another that they can no longer live separately. The relationship between the ants and aphids illustrates mutualism since both organisms benefit. The aphids suck sap from plants and convert it into a milk-like substance which they give off when their bodies are gently stroked by the ants. This material is used by the ants for food. In return, the ants care for and protect the aphids.

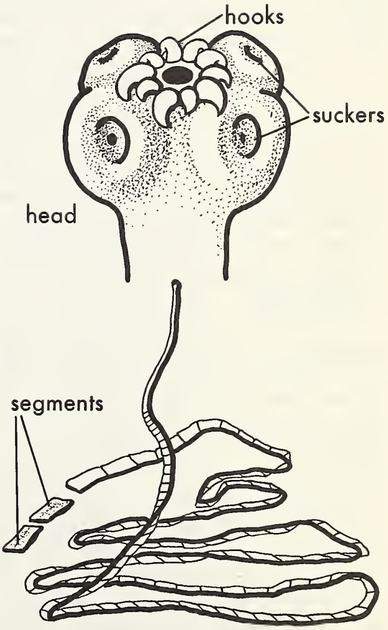


Fig. 40-1. Tapeworm.

(iii) Commensalism is the relationship in which only one member benefits while the other is neutral, i.e. it neither benefits nor is it harmed. Quite literally commensal means table mates. *Remora*, a small fish that attaches itself by means of a sucker to the underside of a shark and feeds on the scraps of food that escape from the shark's mouth is a typical commensal.

Life Processes. To maintain life as mentioned earlier in connection with protoplasm all living organisms must perform certain activities known as the life processes.

Animals spend much time and a great deal of energy in acquiring and processing food so that it can be used. All these activities are collectively referred to as nutrition. Food must be secured from plants or from other animals. The food that is procured by an animal is in such a form that it cannot be used directly, it must be converted to a form in which it can be absorbed and used by the cells. The process of converting foods into a useable form is known as digestion. The whole process is regulated by enzymes, chemicals which change the speed of a chemical reaction, but emerge from the reaction unchanged. Thus they may be used over again.

Once the food materials have been absorbed by the cell they may be used for two purposes. Some are used to repair and replace protoplasm or to produce additional protoplasm in the process of growth. Much of it is used as a fuel to liberate energy. Energy is required by animals in large quantities because of their active life. The processes involved in building up protoplasm and the liberation of energy are known as metabolism.

No food can be used completely nor can it be digested completely. Waste materials i.e. indigestible materials are gotten rid of by a process known as elimination. Generally these materials are simply passed out of the body, in higher animals through the anus.

As the result of metabolism, waste materials like water, urea and carbon dioxide are produced. To get these out of the body special organs are necessary. The kidneys, the skin and the lungs are all involved in passing these wastes out of the body i.e. in excretion.

An animal must be in tune with its surroundings. This ability to respond is called responsiveness or irritability. This requires specialization of protoplasm or cells in complex animals. Higher animals like man have a sensory system consisting of nerve fibres, sense organs and organs to carry out the response.

All animals must have the ability to perpetuate themselves. Without this ability animals become extinct. The process of reproduction results in self-perpetuation. Animals possess special structures or organs for the purpose of reproduction.

The Paramecium. Though Paramecium is a unicellular structure, a protist, by examining its life processes, a great deal may be learned regarding the processes in animals.

These organisms are common in fresh water in which a large quantity of decaying material is found. ***Paramecia*** feed on the bacteria that cause the decay. One may sometimes find them in vases of flowers that have been standing for a long period of time.

Paramecia are barely visible to the naked eye. They may appear as whitish specks moving very rapidly through a drop of water on the slide. When examined under the microscope they appear as flattened ovals somewhat similar to the shape of the sole of a slipper. The rounded end is the front end. As the ***Paramecium*** moves it takes a spiral path, turning over and over.

The entire surface of the ***Paramecium*** is covered with fine protoplasmic threads called cilia. These are uniformly distributed over the entire cell. The lashing of these cilia produces movement.

Along one side of the body there is a depression extending backward about two-thirds of the body length. This depression is called the oral groove. At its base is an opening through the plasma membrane (mouth) into a tubular structure called a gullet. Food particles pass through these structures into the cytoplasm where a food vacuole forms.

Deposited on the outer surface is a structure called the pellicle. It is stiff but elastic and gives the characteristic shape to the organism. Just under the pellicle in the cytoplasm are oval structures which when stimulated discharge protoplasmic darts into the surrounding water. These structures known as trichocysts are thought to function as a defense mechanism.

At each end of the organism is a star shaped structure called a contractile vacuole. It collects excess water from the cytoplasm and expells it from the cell. Without this structure the cell would swell and eventually burst.

There are two nuclei in each ***Paramecium***. They are not of equal size. One is large and is called the macronucleus. The other is small and is called the micronucleus.

Bacteria and other organic debris are swept by the cilia into the oral groove and down the gullet. Here food vacuoles form. Many of these may be circulating through the cell at one time. Enzymes are secreted into the food vacuole and digestion takes place here. The food is then absorbed into the surrounding cytoplasm where it is used to produce additional protoplasm or used to liberate energy.

Part of every food particle is indigestible. Since the organism has a pellicle the waste material can be eliminated at one location only, the anal spot, an opening in the pellicle just behind the gullet.

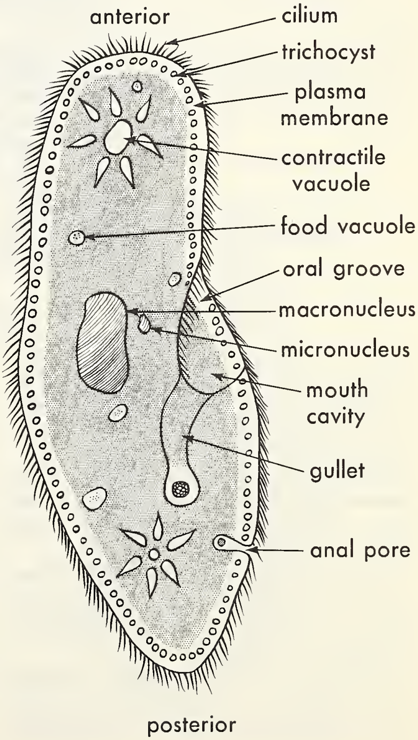
Oxygen, necessary for the liberation of energy, enters the cell at any point by diffusion. Oxidation results in the formation of carbon dioxide, water and other wastes. These must be gotten rid of. Carbon dioxide diffuses out of the cell into the surrounding water. Other wastes are given off through the contractile vacuoles.

Paramecia respond to contact with obstacles by withdrawing. A similar response results when subjected to harmful chemicals like strong acids, bases and salts. Light apparently has no effect since they will neither be attracted nor repelled by it.

To reproduce, ***Paramecia*** will simply divide. This is known as fission. A cell divides to produce two exactly like itself. This type of reproduction may continue for a period of time, but not indefinitely. There is a loss of vigor. To restore vigor, that fission may resume, conjugation must take place. Two cells lie side by side and make contact in the region of the oral groove. The pellicle dissolves at the point of contact and there is an exchange of micronuclear material. The cells then separate and are now able to resume reproduction by means of cell division.

Man, a Multicellular Animal. Though man is multicellular, it is within the cells that all the activities are carried out. Each

Fig. 40-2. Diagram of Paramecium.



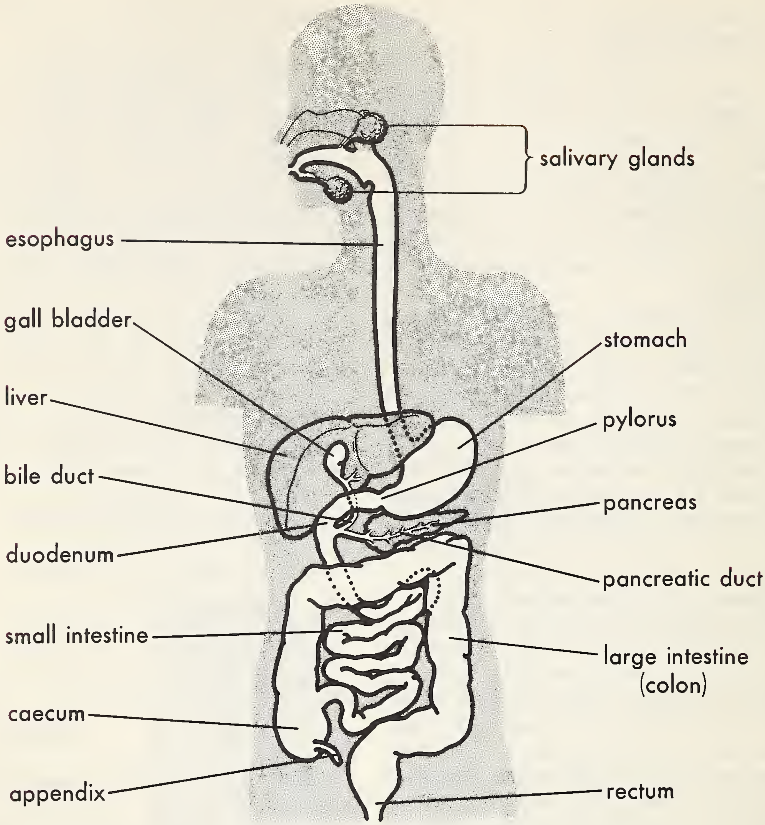


Fig. 40-3. The Human Digestive System.

cell must perform all of the life processes for itself and the activities of the organism are the sum total of the activities performed by the cells.

Digestion in man is not as simple as in ***Paramecium*** although its basis is the same. It occurs in a system known as the alimentary canal.

The process begins in the mouth where food is chewed and mixed with saliva. The enzyme contained in the saliva begins the digestion of starches.

Food passes from the mouth through a tube known as the esophagus. In the stomach more muscular activity mixes the contents with digestive juices produced by the gastric glands located in the lining of the stomach. Digestion of carbohydrates continues and that of proteins begins.

The pylorus, a muscular ring, regulates the passage of materials from the stomach into the small intestine where digestion is completed. Enzymes from the pancreas and intestinal glands aid in this activity. Digested materials are then absorbed into the blood stream for transport throughout the body.

Indigestible materials pass along the alimentary canal into the colon. Here

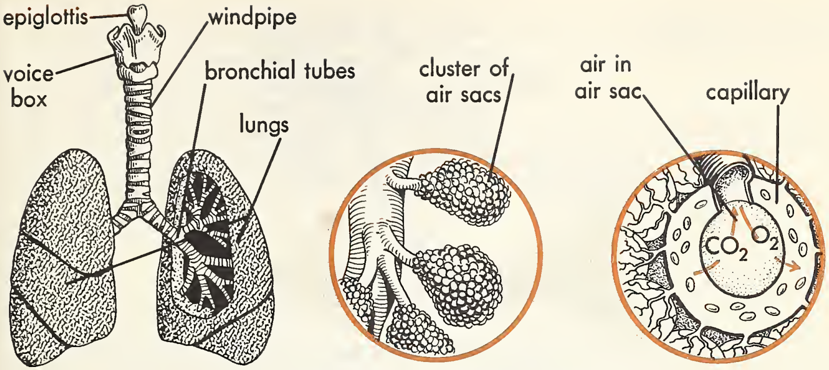


Fig. 40-4. Human Respiratory System.

water is reabsorbed. The relatively firm materials are then eliminated through the anus.

Man, like all animals must have energy for his many activities. This energy is made available through respiration which requires a source of oxygen. In an animal the size of man, special organs for oxygen intake, transport and carbon dioxide elimination are necessary. The lungs are the site of gas exchange with the atmosphere. Oxygen is carried by red cells in the blood stream united with a chemical in the red cells called hemoglobin. The carbon dioxide is also carried by the blood stream but in the form of carbonates. Gas exchange in the lungs and at the cells is by a process known as diffusion.

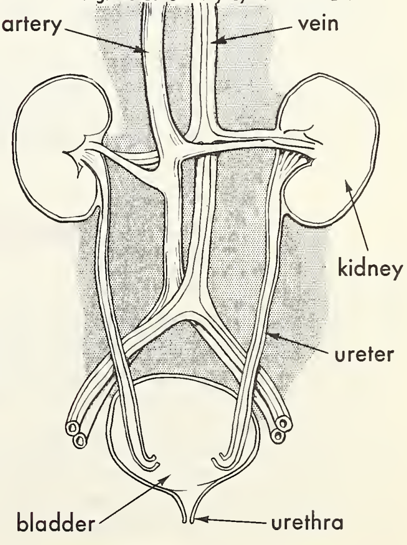
During respiration toxic waste materials called urea are produced. These must not be allowed to accumulate in the body. To excrete urea, man has organs called kidneys. The kidneys extract the urea and pass it along to the urinary bladder where it is stored until it can be given off.

In an animal as complex as man the various parts must be coordinated so that they will function together as a unit. This coordination is the function of the nervous system.

The nervous system consists of three basic components, sensory nerves, the brain and motor nerves. It is the function of sensory nerves to receive impulses from the surroundings and transmit them to the brain where decisions are made. The decision is then transmitted by way of the motor nerves to muscles which carry out the response.

Each nerve cell consists of three parts. The dendrite endings receive stimulations and transmit them to the cell body which contains the nucleus. From here the impulse is transmitted by the axon (away from the cell body).

Fig. 40-5. Urinary system in man.



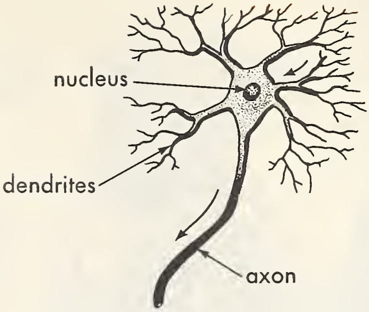


Fig. 40-6. A Nerve Cell.

Things to Remember

Animals are *dependent* forms of life, i.e. they secure nourishment from other organisms.

Animals ***expend much energy*** in the process of living.

Because of the dependent nature of animals they may be grouped according to ***how they secure food.***

Parasite is an organism which secures food or nourishment from other living things.

Mutualist is an organism which associates itself with another organism so that both benefit.

Commensal is an organism that secures nourishment from another living thing but *not* at its expense.

All life processes ***occur within cells.*** In multicellular organisms a life process is the sum total of those occurring in the cells.

In multicellular organisms there is greater ***specialization of cells*** to carry out special tasks, i.e. there is greater ***division of labor.***

Questions

GROUP A

1. Why are animals unable to manufacture their own food?
2. All animals must secure food from what source?
3. What waste materials result from metabolism?
4. What is the term used by the biologist to indicate that an organism is in tune with its surroundings?
5. What is the purpose of the pellicle in *Paramecium?*
6. In higher animals like man, what toxic material is produced as the result of respiration? How is it gotten rid of?
7. What are the three basic parts of a nervous system?

GROUP B

8. Why can we learn much about the processes in man by studying such a simple animal like ***Paramecium?***
9. What processes are included in the term nutrition?
10. What is the main reason for respiration?
11. What would happen to ***Paramecium*** if it did not possess contractile vacuoles?
12. Trace the passage of food through the digestive tract of man.
13. What is the principal purpose of a nervous system in multicellular animals?

Things to Do

The structure of a heart. From a butcher secure the heart of a sheep, pig, or calf. If at all possible have the blood vessels still attached. Before dissecting the heart determine the location of the four chambers. With a sharp knife cut the heart into two longitudinal halves to expose the four chambers. Make a note of the size of the chambers and especially note the difference in thickness of the walls of the chambers. Locate the valves between the auricles and the ventricles. Note the flap-like structure and the tendons which regulate the valves. The valves that prevent backflow of blood may be located at the outlet from the ventricles. By holding them under water and exerting pressure on the heart it is possible to observe the action of these valves.

41

HEREDITY, TRANSMISSION OF CHARACTERISTICS

It has been observed that offspring resemble their parents i.e. monkeys look like monkeys, rabbits look like rabbits and potatoes produce more potatoes. There are, however, differences between members of any given group so that they may be distinguished from one another. Such characteristics as size, coloration and shape are responsible for individual identification. What are the factors which bring about the sameness, yet may also result in subtle individual differences? The answers are provided by a branch of biology known as ***genetics***.

Reproduction. It is necessary to examine ways of reproducing before we can look deeply into questions involving heredity. Basically there are two methods of reproduction:

(i) Asexual or vegetative. This type of reproduction involves the breaking away from the parent organism of a cell or mass of cells which will then develop into an organism like the one from which the original cells came. For example, in the sponge an outgrowth appears. This is known as a bud. It may break away and take up independent existence and form a mature sponge. A more familiar example is the "slip" of plants. A cutting or slip may be taken from a plant like the geranium, placed in water till roots form and then planted in soil. It will grow and produce a plant exactly like the one from which the slip was taken.

(ii) Sexual. This form of reproduction requires the union of two cells before a mature individual may form. The two cells which unite are known as gametes and are of two kinds, the sperm which is produced by the male parent and the ovum which is produced by the female parent. In man and other higher animals it is the only method of reproduction employed.

Cell Division. Two kinds of cells are produced: those involved in reproduction, i.e. gametes and the ordinary cells that make up the body of an organism. An important component of every cell is the set of chromosomes found in the nucleus. The chromosomes are the structures which contain the units responsible for the characteristics of individuals. Each ordinary cell has two sets of these chromosomes. Thus if there are 'n' kinds of chromosomes in a cell, the actual number will be '2n' because the chromosomes are paired. This '2n' number is the diploid number of chromosomes.

Since during gametic reproduction two cells unite, if each were diploid, the chromosome number would double at each generation. To prevent this doubling, a form of cell division which reduces the chromosome number to the 'n' or haploid number takes place. This form of cell division is called meiosis. Cell division which results in growth is called mitosis.

Mitosis. This is a dynamic, i.e. an active continuing process during which the chromosomes double themselves and then distribute themselves to opposite ends of the cell so that it may divide to produce two identical cells. Even though it is a continuous process, certain recognizable phases exist. It is difficult, however, to determine when one phase stops and the next begins.

When the chromosomes cannot be distinguished and the nuclear membrane is intact the cell is said to be in interphase. It is in this phase that each chromosome is thought to produce a copy of itself.

When the chromosomes thicken and become obvious prophase is underway. The nuclear membrane disintegrates and a mass of protoplasmic fibres called the spindle (because of the shape) forms. It is obvious toward the end of this phase that each chromosome is double.

The chromosomes pair up and arrange themselves along the center of the cell in the region called the equator. This phase is known as metaphase.

Under extremely high magnification it is noted that each chromosome is attached to one of the spindle fibres. It is thought that these fibres draw the chromosomes to opposite ends of the cell. The phase during which migration takes place is anaphase.

In the final phase, telophase, the chromosomes cluster at each end of the cell and the nuclear membrane reforms. The spindle fibres disappear and the cytoplasm is divided. In plants, cytoplasmic division results from the formation of a cell wall through the center of the binucleate cell. In animal cells, however, division results from furrowing, a process by which the cell is simply pinched off at the center to form two separate cells.

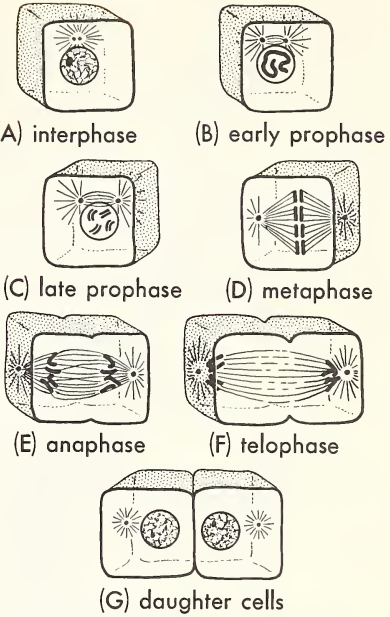


Fig. 41-1. A cell undergoing mitosis.

It must be remembered that mitosis results in the formation of two identical cells. It is by mitosis that growth takes place.

Meiosis. Since all ordinary cells have the '2n' chromosome number, some means must exist for forming cells that will have half that number or the 'n' number of chromosomes. This process is known as meiosis. It is similar to mitosis except that after chromosome doubling takes place, two very rapid cell divisions occur forming four cells, each of which contains one chromosome of each type. In sperm formation, each meiotic division results in four functional cells, whereas in ova formation only one functional cell, the ovum, forms together with three non-functioning cells or polar bodies. These polar bodies disintegrate and are

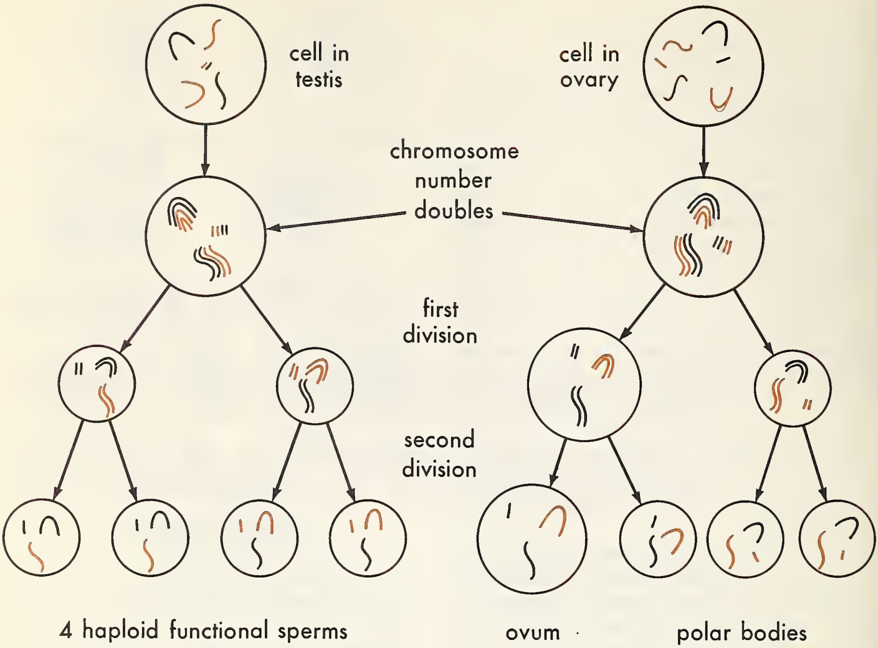


Fig. 41-2. Meiosis.

reabsorbed into the surrounding tissue. Meiosis occurs in special gamete-producing organs, the testis in the male and the ovary in the female.

Gametes must fuse before an organism can develop. This fusion of gametes is known as fertilization (conception) and the resulting cell in which the '2n' chromosome number has been restored is known as a zygote. This zygote, by mitosis, grows to become a mature organism like the ones which originally produced the gametes.

Early Concepts. Man has always been curious concerning himself and all things around him. He noted that under most conditions organisms were like their parents. It was also noted that under certain specific conditions rather startling effects resulted. Man tried to explain these conditions. Because man knew that blood played an important role in preserving life, he attributed to it rather mystical qualities, among them the ability to influence hereditary characteristics. Such terms as 'bad blood' and 'blood is thicker than water' are the result of this belief.

Another concept, that is not entirely dispelled today, is the belief that the environment may influence a developing infant. There are those who believe that a birth mark may be caused by a bad fright, whereas others believe that a hairy mole may result from the mother having been frightened by a hairy animal while she was carrying the child. None of these concepts has any basis in fact.

Gregor Mendel. Much of our knowledge today is the result of the work done by an Austrian monk, Gregor Mendel.

As did many promising young men who could not afford to go to school on their own, Mendel became a priest. In this way he was able to further his studies. Monas-

Fig. 41-3. Photo of Gregor Mendel.

tic life left him with a good deal of time on his hands. He consequently took up the hobby of gardening; but gardening in itself was not his main interest. His principal interest was in the effects of breeding plants. Between the years 1856 and 1864, Mendel carried out careful experiments on peas and kept very careful notes on his findings.

Mendel chose peas as his subject for experimenting because:

(i) peas normally self-pollinate and so are likely to be "pure."
(ii) peas can be easily cross-pollinated to produce new combinations of characteristics, and
(iii) peas possess seven distinct characteristics and thus allow wide testing.

Mendel presented his findings, in 1865, to the Natural History Society of Brünn, the town where his monastery was located. The following year they were published in the scientific journal issued by that group. It was many years before his findings and their significance were noted and used.

In his experiments Mendel found that characteristics were actually paired, e.g. tallness and shortness in peas. When a tall pea was crossed with a short pea he found that all the offspring of this cross were tall. Yet when these were cross-pollinated, he found that some of the offspring displayed the characteristic shortness which had apparently been lost in the previous generation. As a result of this finding Mendel came to the conclusion that each characteristic is controlled by two factors. If both factors are the same, the organism is said to be pure for that characteristic. If the two factors are different the organism is said to be hybrid. In a hybrid, that characteristic which is apparent is the dominant one, whereas that which is apparently lost or obscured is the recessive one.

Mendel found that in peas there are seven pairs of contrasting characteristics:

DOMINANT CHARACTERISTIC	RECESSIVE CHARACTERISTIC
Tallness	Shortness
Green Pod when unripe	Yellow pod when unripe
Tough pod	Soft pod
Smooth seed	Wrinkled seed
Colored seed coat	White seed coat
Yellow seed leaves	Green seed leaves
Flowers along stem of plant	Flowers bunched at top of plant

Mendel's findings regarding dominance and recessiveness of characteristics and his statement of these findings is termed the Law of Dominance.

Certain characteristics when crossed with others appear to be lost. Mendel reasoned that they were not lost but merely obscured by a dominant factor. However, during the meiosis the two factors separate or segregate into different gametes. A gamete is, therefore, able to carry only one kind of factor, either dominant or recessive, but not both. This statement or concept is referred to as the Law of Segregation. Thus it is possible for characteristics to reappear in later generations. An example of this is the reappearance of shortness even though tall plants are crossed.

At the beginning of his experimentation Mendel confined himself to the study of pairs of characteristics such as

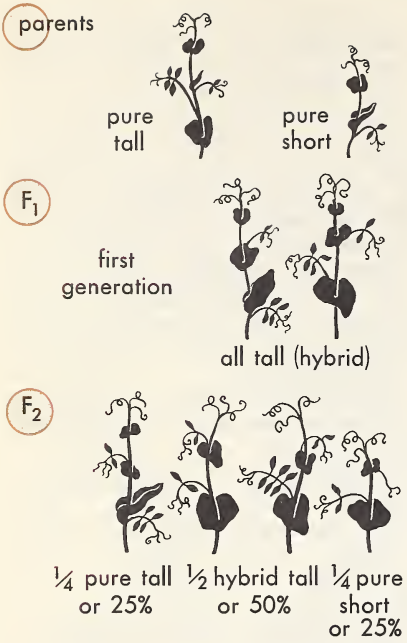


Fig. 41-4. Heredity in garden peas.

tallness and shortness. He later made crosses involving two pairs of characteristics such as yellow round peas and green wrinkled peas. When these were crossed the first generation was all yellow and round. The green and wrinkled characteristics apparently were lost. He then bred these yellow round peas together. Out of every 16 offspring produced he found that there were:

9—yellow round
3—yellow wrinkled
3—green round
1—green wrinkled

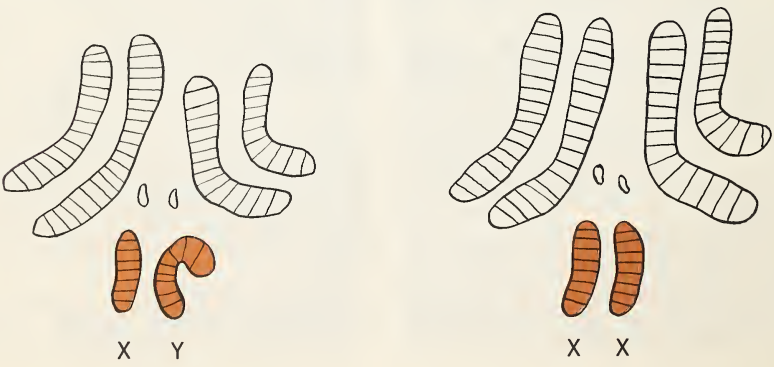
It was apparent that each characteristic is inherited separately from the others. Thus he had discovered the Law of Independent Assortment.

The marvel of Mendel's work is that it was carried out at a time when little was known of gametes and the idea of chromosomes had not yet been conceived. His findings have stood the challenge of time and repeated testing by experiment.

It is now believed that the factors about which Mendel spoke are the genes. These are contained in the chromosomes within each cell. Since each chromosome contains many genes and since chromosomes are transmitted as units, certain characteristics are linked. All those characteristics controlled by genes on a given chromosome are linked i.e. transmitted as a group.

Where there is a distinction between the sexes, it has been found that the main

Fig. 41-5. Sex determination in *Drosophila*.



factor bringing about this distinction is a difference in two of the chromosomes. Normally members of a chromosome pair are similar. However, one pair is made up of chromosomes quite unlike one another. One is designated the X-chromosome whereas the other is designated the Y-chromosome. A combination of two X-chromosomes produces a female where an X-chromosome and a Y-chromosome produces a male.

Genetic Changes. Genes and chromosomes do not always remain unchanged. On occasion, due to reasons not clearly understood, chromosomes may not separate during meiosis. Thus a pair of chromosomes may appear in a gamete. After fertilization there are three rather than two of this particular chromosome. Mongolism, a condition in humans in which the person is mentally deficient and has a pronounced mongolian appearance (hence the name), is caused by this sort of change in chromosome number.

Changes which occur to genes are more common. Radiation such as that produced by X-rays and radioactivity can bring about a change in the chemical nature of a gene and thus change the characteristic which it controls. Such changes in the gene are known as mutations. These can be transmitted from one generation to the next. Frequently mutations are harmful, sometimes fatal. Some common mutations are albino plants and animals, hornless Hereford cattle, new shades of fur in such animals as the mink and fox, resistance to certain diseases on the parts of

Fig. 41-6. The farmer is placing hybrid seed cornin drying racks. Hybrid corn is obtained by crossing two different varieties to obtain certain character-istics such as stiff stalks, resistance to diseases and drought, or ears of uniform size.

plants e.g. resistance to rust in wheat.

Man has carefully bred plants and animals using genetic knowledge to produce those which he considers desirable. By careful selection of those that display the desired characteristics and crossing them, he may produce a new variety.

Marquis wheat, which made possible the growing of wheat in Western Canada during a short season, was produced by Dr. Saunders using scientific selection and breeding. More recent was the development of Selkirk wheat which appeared suddenly as a mutation in a field in Manitoba and now is one of the main rust-resistant wheats grown in Western Canada. New varieties of corn which are superior with respect to flavor and tenderness have been produced by hybridizing.

Thoroughbred horses are the result of very careful selection and breeding. They are bred and selected for very definite characteristics of temperament and spirit as well as strength and speed. This is an example of intensive inbreeding.

Often two very different characteristics are desirable in the same animal. This can be brought about by crossbreeding two animals which display these traits. This has been done with Brahma cattle which are very hardy in hot regions and Aberdeen Angus cattle which are fleshy and tender. As a result, the Brangus is as hardy as the Brahma in tropical regions, but with the meat-producing qualities of the Angus. This new breed is being widely adopted in Australia and some parts of South America and the United States.

Human genetics is not clearly understood since people do not, for social reasons, make good subjects for scientific study. From observation it has been possible to determine some of the hereditary characteristics. We have to content ourselves, however, with the idea that the principles applicable to animals also apply to man.

Things to Remember

Offspring ***tend to resemble*** their parents.

Asexual reproduction results in a continuation of organisms that are exactly like the stock from which they came.

Sexual reproduction, because there are two parents, makes possible a variety of offspring.

Mitosis produces cells which are alike and generally results in growth.

Meiosis produces cells with ‘n’ chromosome number which function as gametes.

Gregor Mendel, in his experiments with peas, discovered genetic principles which are still applicable today.

Mutations are changes in genetic material which affect the characteristics governed by that genetic material.

Questions

GROUP A

1. What is meant by asexual reproduction?
2. What are the gametes? How many kinds are there?
3. What is the purpose of mitosis?
4. What is meant by the diploid number?
5. What is a zygote? How does it differ from a gamete?

GROUP B

6. Why must the chromosome number be halved before fertilization may occur?
7. Trace the phases of mitosis and indicate the important event or occurrence in each phase.
8. What is the difference in method of the dividing of cells between plants and animals?
9. Why did Mendel select that unexciting organism, the pea, for his experiments?
10. Black guinea pigs and white guinea pigs were crossed. The offspring were all black. What Mendelian law does this illustrate?
11. When red four o'clocks are crossed with white four o'clocks all the offspring are pink. Is this inconsistent with Mendel's findings? If so, how?
12. How is the sex of an organism determined?

Things to Do

Variation in living things. Obtain the height of each of your classmates. Do they vary? What is the average height? What is the range in height? Where do the majority of students seem to be with respect of height?

GLOSSARY

Absorption. The process by which water and other materials pass into the cell.

Acoustics. Sound-absorbing and sound-reflecting properties of an auditorium.

Aeration. Oxidation of organic impurities in raw water by impregnating it with common air.

Air mass. A mass of cold, dry air from the polar regions or of warm, moist air from the semi-tropics.

Alloy. A solid mixture of metals. The alloying metal is added to give a desired quality, such as durability.

Alpha particles. Positively charged particles (nuclei of helium atoms) ejected in some radioactive disintegrations.

Alternating current (A. C.). A current that flows first in one direction and then reverses and flows in the opposite direction.

Alternator. A generator for producing alternating current.

Ammeter. An instrument for measuring an electric current in a circuit.

Amplifier. A vacuum tube device to increase the voltage in a circuit.

Amplitude. Extent of a vibratory movement measured from the mean position to the extreme.

Amplitude Modulation (AM). Varying of the intensity of radio waves according to the sound variations to be broadcast.

Anemometer. An instrument that measures wind velocity.

Aneroid. Without liquid. An aneroid barometer.

Anneal. To make glass less brittle by heating it until it is soft and then cooling it.

Annual Growth Ring. The woody tissue in some plants is laid down in rings. This ring represents the growth during one season.

Antibiotics. Chemicals produced by living organisms which destroy harmful bacteria.

Anticline. An upfold or arch of stratified rock.

Anticyclone. A large whirlpool of air at high pressure moving clockwise.

Antiseptics. Chemicals that prevent infection of wounds by bacteria.

Archeozoic era. Period of earliest life in geologic history.

Armature. Coils of insulated wire supported on a shaft that revolves in a magnetic field, used to induce an electric current.

Atomic weight. Sum of neutrons and protons in nucleus of an atom.

Audio amplifier. A device to increase the power of a radio signal.

Axis of earth. An imaginary line about which the earth revolves.

Axon. The part of a nerve fibre whose function it is to carry impulses away from the cell body.

Bacteria. Microscopic, one-celled, parasitic plants.

Ballistic missile. A giant rocket which may be guided or unguided.

Batholith. A great mass of intruded igneous rock originating deep in the earth.

Beaufort scale. Scale from 0 to 12 for measuring wind velocity.

Beriberi. A disease, causing general debility, resulting from a lack of vitamin B in the diet.

Beta particles. Negatively charged particles (electrons) emitted by certain radioactive substances.

Block mountains. Mountains formed by massive blocks due to faulting.

British thermal unit (B.t.u.). The amount of heat required to raise the temperature of one pound of water one Fahrenheit degree.

Calyx. The aggregate of sepals at the base of a flower.

Carbochemicals. Chemicals derived from the distillation of coal.

Carbohydrates. A group of compounds composed of carbon, hydrogen, and oxygen. Sugars and starches are carbohydrates.

Carboniferous period. The geologic period in the late Paleozoic. Coal was formed from the vegetation of this period.

Catalyst. A substance that speeds up a reaction but is not itself affected chemically.

Cathode. The negative pole of an electrolytic cell.

Cathode rays. A stream of electrons.

Cell wall. The outer supporting material of a plant cell, provides protection from injury.

Cenozoic era. The era of recent life in geologic history.

Centrosome. A spherical structure near the nucleus of animal cells, involved in mitotic division.

Chain reaction. A reaction which causes further reactions of the same kind, therefore self-sustaining.

Chlorophyll. A green pigment which traps energy from sunlight and feeds it into the chemical process which results in the splitting of water molecules into hydrogen and oxygen.

Chloroplast. A granule containing chlorophyll, site at which photosynthesis takes place.

Chromatin. The granular contents of the nucleus during the phase of mitosis known as interphase.

Cilia. Protoplasmic projections in some cells.

Circuit. A complete path of an electric current.

Cirrus cloud. A high, thin cloud consisting of ice crystals.

Coarse-grained rock. An igneous rock with large crystals; for example, granite.

Cold front. The face of a cold air mass that pushes back a warm air mass.

Comet. A heavenly body, having a head and a long tail, which travels around the sun.

Commensalism. A relationship between two living organisms in which one benefits but the other neither benefits nor is harmed.

Commutator. A device for reversing the direction of an electric current.

Constellation. A group of stars that seem to form a figure or pattern.

Continental glacier. An ice sheet covering a large area of land.

Continental shelf. A submarine plane bordering nearly every continent.

Contour plowing. A method of soil conservation in which furrows are plowed to follow the curvature of a hill rather than up and down the hill.

Contractile vacuole. A specialized cytoplasmic cavity whose function it is to collect excess water from the surrounding cytoplasm and expel it from the cell.

Corolla. The aggregate of petals of a flower.

Cosmic rays. Extremely high-penetrating rays formed by transmutation of atoms in space.

Coulomb. The quantity of electricity conveyed by one ampere in one second.

Cracking of petroleum. The process of breaking up kerosene molecules to obtain gasoline.

Cumulus clouds. Large, fluffy clouds that develop into thunderstorms.

Cyclone. A whirlpool of air at low pressure moving counterclockwise.

Cytoplasm. The less dense, more watery portion of the protoplasm outside the nucleus.

Decibel. Unit for measuring the loudness of sounds.

Declination. The angle which a magnetic needle makes with the geographic meridian.

Dendrite. The endings of a nerve fibre that receive the stimulation and conduct impulses to the cell body.

Destructive distillation. Decomposition of a complex substance by heat and the condensation of some of the vapors.

Detergent. A cleansing agent, usually a soapless soap.

Deuterium. A heavy isotope of hydrogen.

Deuteron. A nucleus of deuterium.

Dew point. The temperature to which the atmosphere must be cooled to produce condensation.

Diatoms. Microscopic plants which are the source of oil deposits on the sea floor.

Dielectric. A non-conducting material.

Diffusion. The physical process by which molecules pass from a region of high concentration to one of lower concentration until equilibrium is established.

Digestion. Breaking food down chemically by the action of enzymes.

Diode. A vacuum tube used to rectify alternating current to direct current.

Diploid. The chromosome condition in cells in which the chromosomes are paired (2n number).

Direct current (D.C.). A current that always flows in the same direction.

Doldrums. The region on the earth between 10°N. and 10°S. in which there is little or no wind.

Domain magnetic theory. A theory that explains the magnetization of iron.

Dominant. In genetics, refers to that characteristic that is apparent in a hybrid.

Drainage basin. An area of land drained by a river system.

Dust-cloud theory. One of the theories that explains the origin of the solar system.

Edison effect. The "boiling out" of electrons from a hot filament.

Egg. The female reproductive cell.

Electromagnetic. An iron rod magnetized by an electric current flowing through the coil of wires wound around it.

Electromotive force. The force that causes an electric current to flow.

Elimination. The passage of indigestible materials out of the digestive system by way of the anus.

Embryo. A developing organism.

Embryo sac. The structure formed from the spore in the ovule and contains the egg cell.

Emulsion. A dispersion of globules of one liquid in another liquid.

Energy. The ability to do work; may exist in various forms such as heat, mechanical, chemical, radiant, etc.

Environment. The surroundings of an organism, not part of the organism.

Enzyme. An organic catalyst which changes the rate of a chemical reaction but emerges from the reaction unchanged and can be used again.

Epidermis. The outer, protective layer of cells in multicellular organisms.

Equinox. The time when day and night are everywhere of equal length.

Erosion. The wearing away of rock surfaces and removal of loosened material.

Estuary. An arm of the sea at the lower end of a river.

Evolution. The process by whch organisms pass through a series of changes in response to changing conditions.

Exciter. A battery which supplies a current to produce a magnetic field in a generator or motor.

Excretion. The extraction of metabolic wastes and their passage out of the body.

Fall-out. Radioactive dust carried into the upper atmosphere following an atomic bomb explosion, and later brought down by rain.

Fault. In geology, a fracture on the earth in which layers of rock slide up or down along the break.

Fertilization. The fusion of a sperm cell with an egg cell.

Filament. Thread-line metal conductor in a light bulb; a thread-like group of cells; stamen stalk containing the anther.

Filtrate. A filtered solution.

Fluorescence. The emission of white light by a chemical, such as zinc sulfide, absorbing radiations from mercury vapor.

Food. Any material taken in by the body and used for growth, repair of tissue, or the release of energy.

Fossils. Bones, shells, or impressions in rocks of animals or plants that lived in past ages.

Frequency. The number of vibrations (or cycles) per second.

Frequency Modulation (FM). Varying of the frequency of radio waves according to the sound variations to be broadcast.

Front. Boundary between a cold-air and a warm-air mass.

Fruit. The enlarged ovary of a flower containing the seed.

Fundamental. The component of lowest frequency or greatest wave length.

Fuse. An alloy with a low melting point used in an electric circuit to break the circuit when an excessive current flows through it.

Fusion. A combination of the nuclei of light elements with a release of energy; for example, the fusion of hydrogen to helium.

Galaxy. A concentration of millions of stars, such as the Milky Way.

Gamete. A reproductive cell, either sperm or egg.

Gamma rays. Rays given off by radioactive substances; they have no electric charge.

Generator. A machine that converts mechanical energy into electrical energy.

Geosyncline. An enormous subterranean trough in the earth's crust in which deposits collect.

Great circle. The equator, or a meridian of longitude.

Gravitation. The force by which every body in the universe is attracted to every other body.

Half-life. The time required for half the atoms of a radioactive element to disintegrate.

Haploid. The chromosome condition in cells in which the chromosomes are unpaired (n number).

Hard water. Water that does not lather with soap because of calcium and magnesium salts in solution.

Hemoglobin. The iron compound found in red cells whose function it is to unite with and transport oxygen to the cells.

High. An anticyclone; a whirlpool of air at high pressure, generally bringing fair weather.

High-frequency current. A rapid vibration of charges across a spark gap.

Hurricane. An atmospheric disturbance of low pressure that originates over water near the equator and is accompanied by violent winds.

Hybrid. The offspring of two parents who are unlike for a given characteristic.

Hybridizing. The crossing of two different breeds or varieties to produce a new one.

Hydraulic brakes. Brakes which depend on the transmission of force through a fluid.

Hygrometer. An instrument for measuring moisture in the air.

Ice Ages. The periods during the Cenozoic era when ice covered a large part of the continent of North America.

Impervious rock. Rock through which water cannot penetrate.

Inbreeding. The breeding of closely related organisms to produce a given set of desirable characteristics.

Induced current. Production of an electric current by moving a conductor in a magnetic field.

Invertebrates. Animals without backbones.

International date line. Meridian 180°. Vessels crossing the line going west set the date forward by one day, and vice versa.

Ionosphere. Layer of air high above the earth which conducts electricity and transmits radio waves over long distances.

Isobars. Lines on a weather map connecting points having the same barometric pressure.

Isotopes. Atoms of the same element with different atomic weights due to a different number of neutrons in the nucleus.

Jet stream. A high-speed stream of air in the troposphere. It blows from west to east at an altitude of about 30,000 feet.

Kilowatt-hour. Unit for measuring electric energy; 1.34 horsepower-hour.

Latitude and longitude. Latitude is the number of degrees north or south of the equator; longitude, the number of degrees east or west of Greenwich, England.

Light-year. The unit of measurement for the distances of stars from the earth; the distance that light travels in a year.

Lodestone. Iron ore, magnetite, with magnetic properties. Used in earliest compasses.

Longitudinal waves. Sound waves. Waves in which air molecules move in the same line as the waves.

Low. A cyclone; a whirlpool of air at low pressure, generally bringing stormy weather.

Magma. Molten rock within the earth, which ultimately cools to form igneous rock.

Magnetic induction. A magnetizable body becomes magnetized in a magnetic field.

Maritime climate. Small range between summer and winter temperatures.

Meiosis. Cell division in which the chromosome number is halved; formation of gametes.

Mesozoic era. In the earth's history, the period of middle life.

Metamorphic rock. A rock that has been changed by chemical action and pressure.

Meteor. A piece of rock or dust that enters the earth's atmosphere at great speed and becomes incandescent because of the resistance of the air.

Meteorite. A meteor that reaches the earth.

Meteorology. The branch of science dealing with the weather.

Microscopic. So small that it can be seen only under the microscope.

Millibar. A unit of atmospheric pressure. Pressure in millibars is shown on weather maps.

Milky Way system. A galaxy of millions of stars which includes the sun.

Mitosis. Cell division in which exact copies of the original are formed.

Monsoon. A seasonal prevailing wind that blows from one direction part of the year and from the opposite direction the rest of the year.

Moraine. Stones, boulders, clay, and other matter deposited by melting glaciers.

Motor nerve. That nerve which carries the message from the brain to the part of the body that carries out the response.

Mutation. A change in gene structure or number that may be passed from one generation to another.

Mutualism. The relationship between two living organisms in which both benefit.

Narcotic. A drug that relieves pain but induces stupor.

Neap tide. The lowest tide in a lunar month.

Nimbus cloud. A rain cloud, uniformly gray and extending over the entire sky.

Nucleus. The dense portion of the protoplasm which contains the genetic regulators.

Nucleus of an atom. The core. Consists of protons and neutrons. Always positively charged.

Nutrition. Collectively refers to the processes involved in the getting and using of foods.

Occluded front. A meteorological situation in which a warm-air mass is wedged off the ground between two cold-air masses.

Orbit of earth. Path described by earth around the sun.

Organ. A group of tissues together performing a given function.

Organism. Any living thing.

Oscillator tube. Generates alternating currents of specific frequencies in a radio transmitter.

Osmosis. The process by which water passes from a region of high concentration to one of lower concentration through a semipermeable membrane.

Overtone. A sound with twice the frequency of the fundamental tone.

Paleozoic era. The period of ancient life in earth history.

Parallel circuit. An electric circuit in which like poles of a battery are connected to each other.

Parasite. An organism that derives its nourishment from another living organism.

Pasteurization. Controlled heating of milk to destroy bacteria.

Pellicle. A protective covering on some animal cells consisting of protein.

Petal. The delicate, colored structures of a flower.

Petrochemicals. Chemicals obtained from cracking the molecules of petroleum.

Phases of moon. A recurring cycle of changes from new moon, to first quarter, to full moon, to last quarter.

Phloem. The tissue in a vascular bundle that conducts food materials from the leaves to the rest of the plant.

Photoelectric cell. A device for changing light energy into electric energy.

Photosynthesis. The process in green plants in which water molecules are split and the hydrogen thus liberated is united with carbon dioxide to form a simple 3-carbon compound which in turn unite to form glucose.

Pistil. That part of the flower containing the ovule which produces a spore which develops into the embryo sac.

Pitch. The quality of a sound due to the number of vibrations per second.

Planet. One of the nine heavenly bodies that revolve around the sun.

Plastid. A granule in a living cell containing pigments.

Pollen grain. The sperm containing structure formed from the spore produced in the anther.

Precipitation. Rain, snow, hail, etc., that descend on the earth from the atmosphere.

Prevailing westerlies. The winds that blow from the southwest between latitudes 30° and 60° of the Northern Hemisphere, and from the northwest in the same latitudes of the Southern Hemisphere.

Proteins. A class of organic compounds which contain nitrogen as well as carbon, hydrogen, and oxygen. An essential part of a balanced diet.

Proterozoic era. Period of primitive life in earth history.

Pyrenoid. A group of enzymes found on chloroplasts thought to regulate the conversion of sugars into starch.

Radar. Radio direction finding and ranging. A device that locates objects through dense fog and clouds by means of radio waves of extremely high frequency.

Radioactive wastes. The waste "ash" from a reactor; highly radioactive.

Radioactivity. Ejection of rays (alpha, beta, and gamma) from the nuclei of radioactive atoms.

Radiotelephony. Telephony by the aid of radio waves; that is, without connective wires.

Radiotelescope. An instrument that picks up radio waves from planets and stars.

Radiosonde. Apparatus carried by a balloon to the stratosphere to measure air conditions.

Reactor. An atomic furnace used for the fission of uranium.

Recessive. The characteristic that seems to be lost in a hybrid.

Reciprocal. One (unity) divided by the quantity. The reciprocal of a fraction is the fraction inverted.

Relative humidity. Ratio of the actual amount of vapor present in the atmosphere at a given temperature .to the maximum amount of vapor the atmosphere can hold at that temperature.

Respiration. The slow burning, or oxidation, of food in the cells of an animal body.

Responsiveness. An awareness of the environment.

Resonance. Reinforcement of sound. The response of an air column to a vibrating tuning fork.

Reverberation. Reflection of sound waves. An echo.

Rotor. The rotating part of an electric generator.

Scurvy. A disease characterized by hemorrhage of mucous membranes and gums. Due to lack of vitamin C.

Seed. An embryo plant protected by a seed coat.

Semipermeable Membrane. A membrane which permits some materials to pass but prevents the passage of others.

Sensory nerve. That nerve which receives stimulation from the environment and transmits the impulse to the brain.

Sepal. A bud leaf, protects the delicate parts of the developing flower bud.

Short circuit. A circuit formed when an electric current flows through a small resistance rather than through the regular circuit of larger resistance.

Sound barrier. Maximum air resistance against a plane traveling at the speed of sound.

Spectrohelioscope. An instrument for observing solar eruption.

Specific gravity. Ratio of the weight of a substance with the weight of a similar volume of water.

Sperm. The male reproductive cell.

Spring tide. A tide greater than usual. Caused when sun and moon are in conjunction or opposition.

Stalactite and stalagmite. Formations of calcium carbonate resembling icicles on the ceiling and floor of limestone caves.

Stamen. The part of the flower which produces a spore which eventually becomes the pollen grain.

Stomates. Openings in the surface of leaves which permit the passage of gasses in and out of the leaves.

Storage battery. Converts chemical energy into electrical energy. Can be recharged by a current.

Stator. The stationary (non-revolving) part of a generator.

Stratosphere. The outer layer of atmosphere about 40,000 feet above the earth's surface in which there is no weather.

Sunspots. Cooler places on the surface of the sun that appear as dark patches.

Syncline. A downward fold in sedimentary rocks.

Tape recorder. A device that makes recordings on magnetizable tape.

Teletype. A system of communication in which an instrument similar to a typewriter is used.

Terracing. A method of soil conservation in which a long slope is broken into shorter slopes to prevent soil from being washed away.

Theory. A scientific idea to explain an occurence in nature based on a good deal of evidence.

Time belt. A belt 15 degrees of longitude wide. Adjacent time belts differ in time by one hour.

Tissue. A group of cells together performing a specific function.

Tornado. A small atmospheric disturbance of low pressure, starting on a very hot day and accompanied by winds of high velocity that are highly destructive.

Tradewinds. Prevailing winds in the belts 10°-25° north and south of the equator. In the Northern Hemisphere they blow toward the equator from the northeast, in the Southern Hemisphere from the southeast.

Tranquilizers. Drugs to relieve mental stress.

Transformer. A device that changes the voltage of an alternating current. Step-up transformer increases voltage; step-down transformer reduces voltage.

Transistor. A small amplifying device, used in place of vacuum tube.

Transmitter. Part of telephone into which one speaks. Key of telegraph set. Device that sends out radio waves in broadcasting.

Transverse waves. Motion of particles of medium in a plane perpendicular to direction of waves.

Triode. A vacuum tube with a grid that controls current and voltage; it is used in amplifiers.

Tritium. The heaviest istotope of hydrogen.

Troposphere. The thin shell of air surrounding the earth in which weather changes take place.

Tuber. An enlarged underground stem in which surplus food has been stored, e.g., potato.

Ultrasonics. Sounds with frequencies higher than can be heard by the human ear.

Unconformity. Surface of separation between newer and older rock strata.

Unicellular. Consisting of a single cell.

Vacuole. A cytoplasmic space.

Vacuum tube. A sealed tube with most of air removed so that electric discharges can pass between metal electrodes which project into the tube.

Vapor lamp. Light of lamp is a glowing gas caused by passing an electric current through the gas.

Vascular bundle. A mass of tissues in plants, whose function it is to conduct materials up and down in the plant.

Vertebrates. Animals with backbones.

Vitamins. Constituents of foods in their natural state, very small quantities of which are essential for health and nutrition.

Warm front. Part of front between warm and cold-air masses, and warm air replaces cold air at ground level.

Water cycle. Repeated evaporation and condensation in the atmosphere.

Water table. The level of underground water.

Wave length. Distance between crests of successive waves.

Weathering. The wearing away of rocks by wind, rain, cold, and heat.

Xylem. The woody tissue of a vascular bundle whose function it is to conduct water and dissolved minerals upward from the roots to the rest of the plant.

Zygote. The cell resulting from the union of a sperm and egg.

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